AN INVESTIGATION ON THE EFFECT OF ENVIRONMENT COMPLEX ON *Parthenium hysterophorus* L. ITS ADAPTIVE STRATEGIES AND MANAGEMENT THROUGH NON-CHEMICAL PRACTICES.

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BY

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CERTIFICATE

This is to certify that the present thesis entitled "An investigation on the effect of environment complex on *Parthenium hysterophorus* L. its adaptive strategies and management through non-chemical practices" is submitted in full requirements for the degree of Doctor of Philosophy to the University of Allahabad, Allahabad. It is a record of original investigations carried out by Mr. Jai Prakash Singh, in the Department of Plant Pathology & Nematology of the Allahabad Agricultural Institute, Allahabad, who has been working since 1998 under my supervision. This work has not been submitted for a degree to any other university.

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ABBREVIATIONS

ai	:	Active ingredient
A.A.I	:	Allahabad Agricultural Institute
ANOVA	:	Analysis of Variance
%	:	Percentage
B	:	Breadth
BAs	:	Botanical Agents
BW	:	Bound Water
^{0}C	:	Degree centigrade
C.D.	:	Critical Difference
Chl.	:	Chlorophyll
Cm	:	Centimeter
DAS	:	Days After Sowing.
d.f.	:	Dilution factor
E	:	Evening
E	:	Number of epidermal cells per m^{2}
EC	:	Electrical conductivity
F. wt.	:	Fresh weight
Fig	:	Figure
g	:	Gram
GVI	:	Germination Velocity Index
h	:	Hour
ha	:	Hectare
HC	:	Hygroscopic Capacity
l	:	Litre

Kg.	:	Kilogram
L	:	Length
m	:	Metre
M	:	Minute
M	:	Morning
Mg.	:	Milligram.
ml	:	Millilitre
mm.	:	Millimeter
MSS	:	Mean of sum of squares
N	:	Noon
OP	:	Osmotic Potential
PDA	:	Potato Dextrose Agar
Pl	:	Plant
Popn	:	Population
PWC	:	Plant Water Content
RBD	:	Randomized Block Design
RWC	:	Relative Water Content
S	:	Number of stomata per m^2
SI	:	Stomatal index
Sq.	:	Square
SS	:	Sum of squares
TGP	:	Total Germination Percentage
TTC	:	Triphenyl tetrazolium chloride
Viz	:	Namely
WD	:	Water Deficit
Wt	:	Weight

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CHAPTER – I

GENERAL

INTRODUCTION

GENERAL INTRODUCTION

Weed has been defined in Oxford dictionary as small and useless plant growing where it is not wanted. In the absence of natural constraints such weeds grow out of proportions and become a menace.

The waste land weed Parthenium *(Parthenium hysterophorus* L.*)*, popularly known as congress weed, star weed, white top and feverfew, believed to have entered India accidentally in mid fifties, is one of the most dreaded weed species (Rao, 1956). It is an annual herb growing to a height of 1.0 to 1.5m, with profuse flowering throughout the year since it is insensitive to photoperiod and thermal regimes plate I (a b & c)*Parthenium* has unique adaptability to wide agro-climatic conditions and soils. A native of Mexico, West Indies, tropical South and North America, it was first described in India from Pune (Rao, 1956), but has spread to almost all the states in India and established as a naturalised weed. It is found in varying dimensions on waste lands, along road sides, railway tracks, cultivated fields, residential areas, industrial areas and other fallow lands as well as abandoned fields thereby attaining the status of number one weed amongst the terrestrial weed in India plate II (a,b & c) and III(a,b,c & d).

Parthenium has prolific seed bearing capacity producing a minimum of 330 of pollen per m^2 land area, of which 15,000 to 20,000 seeds are produced per plant/year depending upon growth, habitat and longevity. Its high rate of fecundity, efficient seed dispersal mechanisms due to the presence of two persistent disc florets, which act as floats, coupled with adverse allelopathic effects on many species enable its quick spread and establishment (Krishnamurthy *et. al.*, 1977), plate IV (a & b).

Adverse effects of *Parthenium* not only on human beings but also on animal health have been well documented. It is known to cause asthama, bronchitis, dermatitis and hay fever in man and livestock. The chemical analysis has indicated that all the plant parts including trichomes and pollen contain toxins called sesquiterpene lactones. The major components of toxin being 'parthenin' and other phenolic acids such as caffeic acid, vanillic acid, anisic acid, chlorogenic acid, parahydroxy benzoic acid and P-anisic acid are lethal to human beings and animals.

I. ECOLOGY

Impact of *Parthenium* on Agricultural Ecosystem

Parthenium has several built-in properties and efficient behavioural mechanisms, which enable this plant to overcome many ecological adversities and thus continue to survive under stress. Hence, in the absence of any effort, *Parthenium* plant may be able to survive for comparatively a period longer than what is hitherto recorded with other species.

The weed finds access to any type of land apart from its growth in waste lands like road sides, railway tracks, vacant sites, grave yards, back yards, factory premises etc. Though it grows in agricultural lands, gets eliminated along with the regular weeding process where intensive cultivation is practiced. It is not seen when rice is cultivated under puddled conditions (except on the bunds), but this weed grows in dibbled or drilled rice under upland conditions. In agricultural fields where only one crop is taken in a year, it grows in the fallow period with one or two rains but its growth and reproductive ability will be affected depending upon soil fertility and rainfall. *Parthenium* grows profusely in the orchards of guava, coconut, grapes, sapota, mango, cashew, papaya etc. as weeding is not done as

frequently and systematically as in the continuously intense cropped fields. The occurrence of this weed in grasslands is reported to reduce forage production upto 90 percent besides making the land less fertile (Vartak, 1968). The weed has also been seen in association with groundnut, potato and cotton and is reported to have hampered their production considerably in Karnataka (Hosmani *et. al.* 1973).

Some laboratory studies were made on the effect of *Parthenium* on crop plants. The dried and powdered plant materials when incorporated into the soil have been reported to inhibit the germination, growth and yield of wheat (Lakshmi Rajan, 1973) and ragi (Kanchan, 1975). Besides, the water extract from the roots reduced the growth and colonisation of nodule bacteria. Further, the yield of tomato and ragi was reduced by 40 to 50 per cent due to decrease in the number of branches and tillers. The germination of cowpea and beans showed a reduction of 50 and 60 per cent over control, respectively due to the inflorescence and leaf extracts of the weed, while with stem and root extracts, the reduction caused in coleoptile height and dry weight was considerably less. Though the coleoptile height of wheat was not affected much by the extract of fruits, its effect on plant dry weight was severe (Lakshmi Rajan, 1973).

The floristic studies under non-cropped and cropped lands indicated that *Parthenium* had the highest stand in kharif. Density of *Parthenium* was maximum followed by *Cassia tora, Acanthospermum hisipidum* and *Echinochloa crusgalli* under non-cropped lands. (Table1.1). In cropped lands during kharif, *Parthenium* was noted in the fields of soyabean, millets and paddy indicating its adaptability to different soils and moisture levels. A community of *Echionochloa - Digitaria - Parthenium - Acanthospermum*

type was found developed under these habits. (Table 1.2). It has also been found that the *Parthenium* population is high in places where the soils are being disturbed constantly for purposes of construction of buildings, roads etc. Maheshwari (1966), has stated that this has become a neotropical weed which is highly undesirable and can cause much damage.

It is seen growing sparsely in high altitudes like Kollimalai, Nilgiri and Annamalai Hills in Tamil Nadu; Bhagamandala, Biligiri Rangana Thittu and Baba Budangiri hills in Karnataka; and Kuluvalley in Himachal Pradesh. Neither it is seen showing wild growth in hilly regions, nor it is noticed in high rainfall areas like South Kanara and North Kanara in Karnataka and along the coastal line in Orissa, Goa and Kerala, but it is found growing in the east coast of Tamil Nadu and Andhra Pradesh.

To conclude, *Parthenium* can adapt to a variety of agro-ecological situations. It also appears to have its own adaptive and protective measures to tide over various environmental stresses.

Seasonal impact on the intensity of *Parthenium*

Parthenium seeds are capable of germinating growing and colonising during any part of the year even with one or two showers. When the regular rainy season starts late or after first showers, it grows very fast because of its drought resistance thereby suppressing other drought sensitive species plate V (a) *Parthenium* population will be relatively low in its proportion to the rest of the species in the years of good rainfall. This explains why *Parthenium* growth is more rampant in some years than in other years. The intensity as observed in and around Bangalore over calendar months is given in Table 1.3.

Table 1.1: Quantitative parameters of major weeds of *Parthenium* community under non-cropped lands in monsoon and winter.

Tiwari and Bisen (1984)

Weed species	Abundance %	Density %	Frequency %	R. dominance %	R. density	R. frequency	I.V.I.
Monsoon (Kharif)							
P. hysterophorus	7.4	6.3	85	2.2	10.2	4.1	16.5
Cassia tora	7.9	5.9	75	1.3	9.6	3.6	14.5
A. hispidum	8.2	4.9	60	1.6	7.9	2.9	12.0
E. *crusgalli*	8.5	5.5	65	0.6	8.2	3.2	12.0
Winter (Rabi)							
P. hysterophorus	21.2	21.1	100.0	7.1	69.9	18.1	95.0
A. mexicana	1.2	0.24	19.1	17.6	0.7	3.5	21.8
D. annulatum	3.1	1.6	52.4	3.5	5.4	9.5	18.4
M. coromandelianum	1.2	0.5	42.9	5.9	1.7	9.5	17.1

R = Relative IVI = Importance value index

Table 1.2: Quantitative parameters of major weeds of *Parthenium hysterophorus* community in cropped lands (Tiwari & Bisen, 1984).

Weed species	Abundance	Density	Frequency %	R. dominance %	R. density %	R. frequency %	I.V.I.
Monsoon (Kharif) Crops							
E. *crusgalli.*	15.6	9.5	80.0	1.0	13.0	4.8	18.8
D. adscendens.	10.5	7.3	70.0	1.0	10.1	4.2	15.3
P. hysterophorus	7.5	6.0	80.0	3.2	8.2	4.8	16.2
A.. hispidum.	6.7	4.9	75.0	1.6	6.7	4.4	12.7
Winter (Rabi) Crops (Irrigated) Wheat							
P. hysterophorus	8.3	6.7	70.0	6.3	23.1	12.5	41.9
D. adsendens.	6.3	5.7	90.0	2.7	19.7	1.8	24.1
A. arvensis.	7.7	3.1	40.0	1.8	10.7	6.3	18.7
C. album.	2.7	2.2	80.0	2.7	8.6	7.1	17.4
R. dentatus.	4.0	2.0	50.0	3.6	6.9	4.5	14.9
P. minor	6.0	1.1	30.0	2.7	6.2	2.7	11.6
Vegetables							
P. hysterophorus	6.8	5.6	81.8	9.1	23.3	11.4	43.8
E. alba	6.7	3.6	54.6	3.4	15.3	7.6	26.3
E. geniculata	2.8	1.3	45.5	4.5	5.3	6.3	16.1
Berseem							
P. hysterophorus	4.6	3.0	63.6	12.7	21.9	12.5	46.5
C. intybus	1.8	1.2	63.6	7.9	8.4	12.5	28.8
D. adscendens	3.4	1.6	45.6	4.8	10.9	8.9	24.7
C. rotundus	5.0	1.4	27.3	3.2	2.6	5.4	18.2

R = relative IVI= Importance value index

A study on growth pattern of *Parthenium* under different niches revealed that plant growth was higher in cropped lands than in non-cropped lands and under irrigation rabi population looked more vigorous. The growth of the winter survived plants was almost suspended and they remained in the "rossette" form till moisture rejuvenation plate V b. After the rains, these plants resumed growth and flowered normally. Generally, the life span of the plant increases to about 335 days under moisture stress conditions. vis-a-vis 212 days under normal conditions

Survey of plant biodiversity

A survey of common waste land weed species carried out in the State of Karnataka revealed that ten species have definite relation with the spread of *Parthenium.* (Tables1.4-1.6). A glance at these tables lends support to infer that in each region there are predominant botanical agents resisting the entry of *Parthenium* weed and some associate (comparatively less dominant) species probably with relatively low allelopathic influence.

It will be seen that *Cassia sericea* is predominant in the three high rainfall districts of transition belt; *C. tora* in two and districts and *C. occidentalis* in two heavy rainfall districts. *Tephrosia purpurea* is observed as an associate species with other dominant species at least in ten low rainfall districts which is noteworthy. *Amaranthus spinosus* is predominant in Bangalore urban area and *Croton bonplandianum* in Mysore district. Mamatha and Mahadevappa (1988 and 1992), based on preliminary surveys have reported that *C. sericea, C. tora, T. purpurea* and *C. bonplandianum* resisted *Parthenium* invasion in many states in India as observed during late eighties.

Table 1.3: Relative density of *Parthenium hysterophorus* plants in different months.

Month	Number per 100 m^2 area (Mean of three random locations)
January	70
February	130
March	230
April	190
May	290
June	290
July	400
August	650
September	450
October	400
November	320
December	210

II BIOLOGY

Carrot weed belongs to the family Asteracae (Compositae). type Helianthae and subtribe Ambrosiinae. It has close affinities with *Ambrosia* and *Hymenochlea*. It has probably been originated from natural hybridization from the two closely related species viz. *Parthenium confertum* and *Parthenium bipinnatifidum* It is rather difficult to determine accurately the natural origin of *Parthenium hysterophorus* due to its world-wide distribution. The presence of *Parthenium* in Indian populations suggests that *P. hysterophorus* was introduced from North America. The double chromosome number for the Indian species from Poona has been reported to be 18 (Hakoo, 1963). Whereas double chromosome number for Northern and Central Mexico populations has been reported 36. It is of terrestrial habit. The plant is a herbaceous, erect, annual 70 to 130 cm in height, usually having 4 to 7 branches with a number of sub branches.

The average basal diameter of the plant is 1.8 cm with length of main shoot varying from 10 to 20 cm. Leaves are 7 to 12 cm long, alternate, leaf margins are deeply serrated and resemble the leaves of Chrysanthemum plant. The number of leaves per plant varies from 20 to 75. The inflorescence is terminal or axillary. The entire plant is covered with very small silvery hairs. The plant keeps on flowering and seeding whole year (Pandey and Dubey, 1988). The seeds germinate within a week wih the onset of monsoon and flowering starts after a month and continues upto another three months. The plant prefers moist, shady and rich organic habitats and can adapt very well even in environmental extremes. The flowering and maturity are non-synchronous. The seeds have no or variable dormancy and 2 to 3 generations of this weed can be seen in the same year

Table 1.4 : Pattern of invasion by *Parthenium hysterophorus* in the colonies of native flora in the waste lands of Karnataka. (Mahadevappa et. al. (1944).

Places	Colonies observed to resist *Parthenium* invasion/entry		Year*	Percentage distribution of *Parthenium* in relation to vegetation Assemblage**
	Predominant species	Associate species		
Bangalore (city and peripheral areas)	1,7,4,5	8,9,6,10	1991-92	Moderate
Bangalore (Rural)	5,7,4,8	1,6,10	1991-92	Moderate
Belgaum	4,5,3,2	1,6,9,7	1990-91	Low
Bellary	4,5,10,7	1,6,9	1991-92	Low
Bijapur	4,10,5	1,6,9	1991-92	Low
Chikmagalore	3,10,5,2	1,6,4	1990-91	Low
Chitradurga	4,10,5,3	1,6,9,10		Moderate
Dakshina Kannada	No *Parthenium* was seen		1987-92	Nil
Dharwad		10,1	1990-91	Low
Hassan	4,5,10,3	6,4,2,9	1991-92	Moderate
Kodagu	3,5,10,7	6,2	1991-92	Low
Kolar	3,5,2	1,8,6	1991-92	Low
Mandya	5,7,4,10	3,2,1	1991-92	Moderate
Mysore (Rural)	5,7,6	2,5,1,9	1991-92	Very High
Mysore (City and peripheral areas)	6,3,7,10	8,10	1991-92	Moderate
Raichur	5,3			
Shimoga	4,10,5,2	10,6	1990-91	Low
Tumkur	4,5,2,10	1,6,9,7	1991-92	Moderate
Uttar Kannada	5,7,4,8	1,6,10	1990,91, 92	Moderate
	No *Parthenium* was seen		1987-92	Nil

* Rainy season (June-October), ** Low - 0 to 25%, Medium - 26 to 50% High - 51 to 75%, Very High - 75% to 100 %

1. *Amaranthus spinosus*
2. *Cassia sericea*
3. *Hyptis suaveolens*
4. *Cassia auriculata*
5. *Cassia tora*
6. *Ipomoea muricata*
7. *Cassia occidentalis*
8. *Croton bonplandianum*
9. *Sida spinosa*
10. *Tephrosia purpurea*

Table 1.5 : Extent of establishment of *Parthenium hysterophorus* plants in the waste lands colonised by various plant species during (1991-92). (Mahadevappa et.al. 1994)

Dominant species in the waste land	Number of plants	
	Vegetation undistrurbed	Vegetation cleared/or soil exposed
1. *Cassia tora.*	7	44
2. *Cassia sericea.*	5	30
3. *Cassia auriculata.*	16	9
4. *Cassia occidentalis.*	41	36
5. *Tephrosia purpurea.*	8	41
6. *Hyptis suaveolens.*	0	31
7. *Sida spinosa.*	0	28
8. *Croton bonplandiamum.*	5	22
9. *Amaranthus spinosus.*	6	49
10. *Ipomoea muricata.*	25	31

Table 1.6 : Interference among waste land species and their impact on *Parthenium hysterophorus* suppression.

Sl. No.	Species	Extent of *Parthenium* suppression*
1.	*Amaranthus spinosus.*	High
2.	*Croton bonplandianum* Baill	High
3	*Cassia occidentalis* L.	High
4.	*Cassia tora* L.	High
5.	*Cassia sericea* SW.	Very High
6.	*Cassia auriculata* L.	Moderate
7.	*Hyptis suaveolens* Poit.	Moderate
8.	*Ipomoea carnea* .	Very High
9.	*Mirabilis jalapa.*	Very High
10.	*Sida spinosa* L.	Moderate
11.	*Tephrosia purpurea* Pers.	Very High
	*Moderate	26 - 50%
	High	51-75%
	Very High	76-100%

depending on the intensity and frequency of winter rains. Its growth remains stunted from November to January due to severe cold. Seed germination has been reported to increase with temperature from 10 to 30 ^{0}C and optimum temperature range is 25 to 30 ^{0}C (Jayanth, 1987).

In north-west India it germinates mainly in the months of February-March, attains peak growth in June-July and produces seeds in September-October, completing its life cycle in 180-240 days. Phytosociologically the plant is a rapid colonizer and competes out other vegetation in its vicinity within two growing seasons. The successful spread of this weed in India may be attributed to its allelopathic properties (Marsie and Singh, 1987). The allelopathic effects of this weed are due to exudation of phytoinhibitors from the aerial vegetation (Parihar and Kanodia, 1987). Large plants can produce more than 15,000 seeds which can be distributed by floating on water or in mud adhering to animals, vehicles and machinery (Auld *et al* 1982).

III DISTRIBUTION

A. Spread in India

It was first noticed in Maharashtra (Pune) during 1955 as a stray plant on the garbage by Professor Paranjape and was later identified and described by Rao (1956). But in a short period, it has spread all over Poona covering waste lands, railway yards, marshy patches, followed cultivable lands, grasslands, roadsides, along the canals and other areas (Maheshwari 1966; Santapau, 1967). The 1958-59 floods in Poona are believed to have helped the dispersal of this weed initially. Subsequently after Panshet dam, in the floods that broke out during 1961, most of the grain godowns near the river

banks were washed out. Linked with this was the rapid spread of this weed all over Maharashtra in a matter of a few years (Ranade, 1975). By about 1965, it stretched to most of the agricultural lands in Maharashtra (Vartak, 1968). Evidently, it could spread to other parts of the country from Maharashtra through vehicular traffic, trains, cargo, packaging material, besides others natural agencies of dispersal (Table 1.7)

It has been observed that *Parthenium* was absent in Coastal Karnataka, Coastal Orissa, Jammu and Kashmir, Pondichery, Northern parts of Haryana and was sparsely growing in the peripheral regions of forests in hilly districts of Karnataka. Based on the reports of the survey conducted by the various authors and also self assessment the order in which it looks serious is in the sequence as fallows Uttar Pradesh, Karnataka, Maharashtra, Tamil Nadu, Andhra Pradesh, West Bengal, Madhya Pradesh, Gujarat and Bihar. It is not seen in the West coast, high attitude and interior forests.

B. Spread in other countries

Though it is native to Mexico, West Indies, tropical South and North America, its spread is not only restricted to these countries but has also been reported from other parts of the world in addition to India as detailed in Table 1.8

IV MENACE

Eversince *Parthenium* started invading newer areas and growing in high population, its numerous ill effects on human and livestock health, native flora and agricultural productivity are being reported frequently.

Table 1.7: Spread of *Parthenium hysterophorus* in India.

State	Areas	References
Andhra Pradesh	Hyderabad, Krishna, Godavari, Chittoor and Nagarjun Sagar areas. Tirupati hills and Khadala. Amaravati, Nalla Malais, Karnool, Maha-oobnagar, Thimmapur, Waltair, Vijayawada and Moosa river.	Krishnamurthy et al (1977). Santapau (1967). Mahadevappa (1996).
Bihar	Mothihari, Narkatiarganj, Balmikinagar Gangetic plains of Bihar	Maheshwari and Pandey (1973). Suresh Chandra (1973).
Gujarat	Ahmedabad, Anand and Baroda	Mahadevappa (1996).
Haryana	Rohtak, Hissar and Faridabad, Eastern parts of Haryana	Mahadevappa *et. al.* (1990).
Himachal Pradesh	Kullu and Manali	Vaid and Naithani (1970)
Jammu & Kashmir	Throughout the state	(Personal communication). Prabhakar (1998).
Karnataka	Dharwad. Banglore, Mysore, Arsikere, Belur, Bhadravati and Shimoga. Kodagu, South Canara and North Canara. Bijapur, Belgaum, Gulbarga, Bidur, Chitradurga, Shimoga, Hassan, Mandya and Tumkur.	Mahadevappa *et. al.* (1990). Jayachandran (1971). Mahadevappa (1996). Newspaper publications.
Kerala	Palghat, Quilon, Kottayam, and Kasargod.	Mahadevappa (1996).
Madhya Pradesh	All over the state except in hills.	Tiwari and Bisen (1984).
Maharashtra	Mumbai city (Juhu area) Forest nurseries Joshi Estate	Tiwari and Bisen (1984). Chandras (1970). Mahadevappa (1996).
Orissa	Not much only in the peripheral parts	Mahadevappa (1996).
Punjab	Many parts of Punjab	Mahadevappa (1996).
Pondichery	Scattered distribution throughout the state	Mahadevappa (1996).
Rajasthan	Udaipur	Mahadevappa (1996).
Tamil Nadu	Kotagiri of Nilgiri hills, Aliyar submergenic area, Coimbatore Katpadi, Jalapet, Madurai, Sulem, Tanjore	Bidhas Ray (1975). Mahadevappa (1996).
Uttar Pradesh	Pantnagar, Rae Bareli, Jhansi Haridwar	Elis and Swaminathan (1969). Mahadevappa (1996).
West Bengal	Calcutta, Bank and Basin of Rivers	Krishnamurthy *et. al.* (1977).

Table 1.8 : Global spread of*Parthenium hysterophorus*

Country	Provinces	References
USA	Florida, Texas, North of Massachussetts, Pennsylvania, Ohio, Michigan, Illinois, Missouri and Kansas	Castex et al. (1940). Arny (1987). Fernold (1970).
Mexico	Throughout the country	Arny (1987)
Argentina	Large area, province of Cardoba	Castex *et. al.* (1940)
Trinidad	Large areas - major problem	Krishinamurthy *et. al.* (1976)
Guyana	Large areas - major problem	Krishinamurthy *et. al.* (1976)
Jamaica	Large areas - major problem	Krishinamurthy *et. al.* (1976)
Australia	Queensland, Central Highlands and North Clermonth. New South Wales	Dale (1980)
South Africa	Large areas	Maheshwari (1966) Vaid and Naithani (1970) Maheshwari and Pandy (1973)
Mauritius	Large areas	-do-
Rodriguez	Large areas	-do-
Sychelles	Large areas	-do-
Bourbon	Large areas	-do-
North Vietnam	Large areas	-do-
Bangladesh	Not in alarming proportion	Mahadevappa (1996)

A Effect of *Parthenium* on human beings

With the first from Texas, USA contact dermatitis due to this weed has long been recognised (French, 1930). Khan and Grothaus (1936) reported a number of cases from Texas and the seasond eruption of exposed skin surfaces happened to coincide with the growing season of this plant. It has been observed that attainment of acuteness of the disease due to this weed inflicting more than 50 per cent of the contact dermatitis caused by weeds specially in southern parts of the United States. He observed chronic lichenified Eczema of the exposed skin surfaces, which tended to be perennial owing to continuous exposure to the weed. Further, clinical confirmation was obtained through positive patch test with the leaf of *Parthenium* on four patients at Louisiana Iden, 1957. Even the related *P. argentatum* species had been reported to cause allergic contact dermatitis. (Smith and Hyghes, 1938).

In Poona, it was detected as an etiological factor in causing eczematoid dermatitis in 29 cases, the pollen of this weed being the main cause. Further study revealed 96 cases of dermatitis to be due to this weed (Ranade, 1975). It has been observed that dermatitis of the exposed skin surfaces in adult males engaged in agricultural work during 1965, attributing it to occupational exposure to *Parthenium.* They indicated that the allergic people are very much prone to the development of eczematoid dermatitis on contact with this weed. There are also reports from Bihar on the development of dermatitis in the local people while cutting this weed for fire wood (Suresh Chandra, 1973). By 1974, the weed attained epidemic status. (Lonkar *et. al..*,1974). Similarly, at Coimbatore, both men and women developed allergic symptoms on repeated contact with the weed. Further,

women developed cracks all over the sole, specially in the heel (Sundara Rajulu and Gowri, 1976). There are evidences of allergic papilla in school boys when they uprooted *Parthenium* in Hassan (Krishnamurthy *et. al.*. *1975).* Further, it has been observed that chances of getting sensitised to the weed are high, when a person comes in contact with the weed for period ranging from 3 to 12 months (Subba Rao *et. al.* 1976). These authors further observed high frequency of the disease in males than females in the ratio 10:1 and the disease was not observed before puberty. They also opined the chances of spontaneous recovery from repeated topical applications despite continued exposure to the allergins.

Ranade (1975 and 1976) developed a vaccine for desensitisation of people suffering from the disease treating more than 400 cases with 20 daily injections with effect lasting for more than 6 months in farmers and for more than a year in urbanities. Chances of relapses were also common. Nevertheless, the booster doses once a year before monsoon (June -July) kept the patients free throughout the growth of the weed during the year. About 8 per cent of the patients so treated were free from the trouble as observed over 5 to 6 years. About 55 individuals were suffering from *Parthenium* allergy in Bangalore city. In one case, a lady aged forty years was drawing out water from her skin to the extent of 1.0 to 1.5 litre per day during peak season of *Parthenium* growth. But she lived normally in a *Parthenium* free environment or when the *Parthenium* population existed in small proportions in the neighbouring fields. In another case, a man aged 47 years suffered from eruptions disfiguring his face and had to sell away his house in an extension area due to heavy infestation of this weed and went back to his old residence in down town area where he could get relief. The

Table 1. 9: Effect of *Parthenium hysterophorus* on human health and live stock.

Disorder	Reaction	Reference
Contact dermatitis	Seasonal eruption of the exposed skin surface	French (1930), Khan and Grothaus (1936)
Eczema	Chronic lichensified eczema of the exposed skin surfaces	Ogden (1957), Smith and Hyghes (1938)
Eczematoid dermatitis	Skin eruptions and itching	Ranade (1975 and 1976)
Eczematoid dermatitis	- do -	Suresh Chandra (1973)
Dermatitis	- do -	Lonkar *et. al.* (1974)
Allergic reactions	Cracks all over the sole	Sundara Rajulu and Gowri (1976)
Allergic papules	Sore throat, bubbles in the mouth	Krishnamutry *et. al.* (1975), Subba Rao *et. al.* (1976).
Fatigueness	General weakness and skin eruptions	Mahadevappa (1996).
Severe dermatitis	Loss of scalp and body hair, ridging on nails	Krishnamurthy *et. al.* (1977)
Fever in cows	Inflamed udder and rashes	Krihnamurthy *et. al.* (1977)
Hypersensit-ivity in rabbit	Restlessness, natural falling of hairs from the dorsal region of the neck and back, small boills and oozing of blood.	Sundara Rajulu and Gowri (1976).
Ulcerations in buffaloes, horses, donkeys, sheep and goats	Acute and chronic toxicity, ulcers both in the mouth and digestive tract, oesophagus and absomal folds. necrosis of kidney and liver.	Subba Rao *et. al.*. (1976).

details of the disorders and symptoms produced thereof are presented in table1.9.

B. Effect of *Parthenium hysterophorus* on livestock

Though cattle do not normally eat *Parthenium*, its ill effects were observed on them when they walked by or grazed through patches of this weed. Such cows had inflated udder and subsequently suffered from fever and rashes (Krishnamurthy *et. al.* 1977).

Krishnamurthy *et. al.* (1977) observed cows (milking or otherwise), buffaloes, horses, donkeys, sheeps and goats eating this weed, besides poultry birds pecking the flowers. Their main concern was about the probable contamination of the milk with the active ingredient 'Parthenin'. Sundara Rajulu and Gowri (1976) studied the harmful effect caused due to repeated contact with *Parthenium* on a young rabbit by letting it free to move about in densely infested weed at Coimbatore. The rabbit exhibited hypersensitivity by showing restlessness from the eighth day onwards. After 3 days, natural falling of hairs from the dorsal region of the neck and back was observed. Eruption of small boils all over the neck and lateral sides of the trunk on the 12th day led to oozing of blood on the 13th day and mortality on the 17th day. It was, therefore, concluded that the weed would be hazardous to animals too. However, the studies in this regard need to be extended to other animals also, for precise information on hazardousness.

It is reported that feeding the weed to buffaloes and bull calves at different levels causes both acute and chronic forms of toxicity (Table 1.9). Ulcerations were caused both in the mouth and digestive tract. Autopsy of the dead animals showed punched out ulcers on the oesophagus and the absomal folds. Histopathology of the kidney and liver revealed degenerative changes and necrosis (Subha Rao *et. al.*, 1976). They further reported that "labelled parthenin" was found to be excreted in the milk when administered

to lactating guinea pigs, rabbits and cows. Consumption of milk containing parthenin could be hazardous to man.

With the information available from various reports and from our own surroundings, it is certain that this is not a humble weed. Though more medical studies are needed, none would doubt its health hazards. In the light of above, it is evident that sound efforts are needed to keep the weed under control.

V. POTENTIAL USES

Instead of eradication of *Parthenium,* its constituents can be used for useful purposes. Information is available on the possibility of utilization of *Parthenium* as a green leaf manure, biopesticide and also as a compost for crop plants.

A. Green Manure Value

In case of rice, the effect of *Parthenium* green leaf manure on plant height was comparatively less as compared to other green manures like leucaena and sunhemp. Whereas, in the ratoon rice crop*Parthenium* green leaf manure was superior in influencing the plant height (Sudhakar, 1984). Similarly in the main crop, *Parthenium* green leaf manure produced less number of filled grains while it produced the highest number of filled grains in the ratoon crop. Among the green leaf manures tried, the residual effect for dry matter production was the highest with *Parthenium* as green leaf manure. In the ratoon crop, *Parthenium* recorded the highest grain yield at 100 kg N per ha level.

B. Compost

To assess the manurial value of*Parthenium* and its composting value, an experiment was conducted and compared with other organic wastes. The

organic wastes tried were coir pith, *Ipomoea,* water hyacinth, *Parthenium,* paddy straws and sugarcane trash. Composite culture consisting of*Pleurotus sojarcaju* and *Trichoderma viride* were used as inoculants for hastening the process of composting. In about 40-50 days good quality compost was obtained (Son, 1995).

Wide variation in the nutrient content of the organic wastes was noticed. The total N content was in the order as*Parthenium* > *Ipomoea* > water hyacinth > sugarcane trash > paddy straw > coir pith wheareas the total P was in the order of *Ipomoea* > *Parthenium* > water hyacinth > sugarcane trash > paddy straw > coir pith. The total K was in the order of paddy straw > coir pith > sugarcane trash >*Parthenium* > water hyacinth > *Ipomoea.* Regarding the biochemical parameters, *Parthenium* and coir pith recorded the highest phenol content.

The organic carbon content varied among the waste. The decomposition of organic carbon was greatly influenced by microbial inoculants. In general, all the inoculants reduced the organic carbon content of the wastes during decomposition and the reduction was to the tune of 36.23, 28.38, 21.23, 17.99, 25.18 and 25.96 per cent over control for coir pith, *Ipomoea,* water hyacinth, *Parthenium,* paddy straw and sugarcane trash, respectively. This could be attributed to the role of microbial activity due to the addition of inducers to the wastes for composting (Nagarajan*et. al..,* 1985). The increase in N content was 4.02, 1.78, 1.60, 1.70, 2.86 and 3.29 folds over control for coir pith, *Ipomoea,* water hyacinth,*Parthenium,* paddy straw and sugarcane trash, respectively. The increase in the total N content of wastes was due to the decomposition of the carbon and increasing the inorganic elements (Rajendran, 1991).

The C:N ratio was markedly reduced by the inoculants in all the organic wastes. Among the organic wastes, coir pith recorded the highest

reduction in C:N ratio followed by sugarcane trash, paddy straw, *Ipomoea,* water hyacinth and *Parthenium.* The reduction in C:N ratio was the result of decrease in carbon content which was utilized as the energy source for the soil microflora and consequently converted into the N content. Similar results were reported by Nagarajan *et. al.* (1985), Rajendran (1991) and Thilagavathi (1992). *Parthenium* compost recorded higher K content. The phenol contents varied from waste to waste compared to the initial values on 42nd day of composting. The reduction in phenol content was substantial in all wastes. The highest percentage of reduction in phenol content (41.4%) was observed with *Parthenium* eventhough the phenol content was higher in *Parthenium* at the end of composting.

C. Response of crops to *Parthenium* compost

Field experiments were conducted with rice followed by soyabean, maize and cowpea using the composts prepared out of different organic wastes. All the organic waste composts including *Parthenium* enhanced the organic carbon status of the soil indicating beneficial effect of incorporation of wastes. The highest increase was to the extent of 22.6 and 20.8 per cent over NPK alone due to application of composted *Parthenium* at flowering and harvest stages, respectively. Among the treatments, *Parthenium* composts recorded higher available soil N at post harvest stage. This could be attributed to the higher N content of *Parthenium* compost than other composts from organic wastes.

All the organic waste compost recorded higher grain yield of rice as main crop over NPK alone. Similarly, all the organic waste composts recorded higher grain yield of maize as main crop over NPK alone.

In the case of residual crops of soyabean after rice, cowpea after and maize, the *Parthenium* compost application to the main crops recorded the

highest yield of 1917 kg per ha and 1285 kg per ha, respectively as compared to other organic waste composts and application of NPK alone. This residual effect of *Parthenium* can be exploited for beneficial use.

D. Biocontrol value

The weed population in rice field was found to be influenced by the incorporation of composted organic wastes. Among the treatments the composted coir pith and *Parthenium* recorded lower weed population. The application of organic waste composts reduced the weed count from 30.5 to 39.8 percent over N.P.K. at 60 DAT. This could be attributed to the role of allelopathic compounds such as phenol present in these two debris even after composting (Son, 1995). Similar reduction in weed population due to *Parthenium* as green leaf manure for rice reported earlier by Sudhakar (1984). Among the different composts, coir pith and *Parthenium* compost recorded lower weed population in maize.

The beneficial effect of organic wastes in reducing the incidence of pests such as stem borer and leaf roller was observed due to the application of organic waste composts. Generally under incorporation of organic wastes, the reduction in pest incidence was to the extent of 43.4 to 50 per cent at 60 DAT as compared to NPK alone (Son, 1995). Incidence of leaf roller in rice crop was the highest with urea application, whereas it was the lowest with *Parthenium* as green leaf manure application (Sudhakar, 1984). This biocontrol behaviour of *Parthenium* can be exploited.

Thirteen fungal species such as *Aspergillus candidus, A. flavus, A. fumigatus, A. glaucus, A. niger, Alternaria alternata, Curvularia pallescens, C. lunata, Fusarium equiseti, F. oxysporum, Penicillium notatum, Rhizopus arrhizus* and *Trichoderma ignorum* were isolated from the phyllosphere of young, mature and senescent but healthy leaves of *Parthenium*. The total

population of microorganisms showed considerable increase from young to mature to senescent but healthy leaves (Dhawan and Dhawan, 1995).

However, if some strain of any of these fungi are developed which meet the requirements of using them as biocontrol agents i.e. host specificity and strong virulence, only then they can be considered as potential bioherbicides for biocontrol of *Parthenium* (Dhawan and Gupta, 1996).

E. Soil amendment value

Any organic waste application aids in moisture conservation which is utilised for better root penetration and crop growth. In general, incorporation of organic wastes enhanced the moisture content of the soil to the tune of 45.5 to 77.4 per cent as compared to application of NPK alone to maize crop (Son, 1995). This enhancement could be attributed to higher water holding capacity of the soil due to the influence of organic waste application. The moisture in soil due to application of *Parthenium* compost was 14.5 and 16.5 per cent at (0-15, 15-30 cm depths as compared to 10.7 and 11.6 percent at 0.15 and 15-30 cm depths of soil due to application of NPK alone. This may be due to building up of organic carbon status in soil. This behaviour can be utilised for moisture conservation practices.

F. Allelopathic effect

Allelopathy is an expression of a general phenomenon chemical interaction and are known to inhibit seed germination by inhibiting hydrolysation of reserve food, division and several other factors (Rice, 1974). An experiment conducted on allelopathic effect of *Parthenium* leaf extract on sunflower and sorghum revealed that the germination percentage, shoot and root length, dry weight and vigour index decreased with an increase in the concentration of *Parthenium* leaf extract from one to 10 per cent (Murthy *et. al.*, 1995).

VI Significance of the present study

Although herbicide application and disposal with mechanical devices like flame thrower have considerable merits, being cost effective and provide immediate solution to most weed problems, butthey are not only or necessary best solution because of rising expenses and need for continued treatment. Beside chemical pollution, enormous cost, danger of toxicity to non target plants, treatment in non agricultural areas, rapidity of reinvasion of treated areas soon after the effect is diminished are known drawbacks of chemical control. Moreover, weedicide may also kill the non-target harmless weed flora. High concentration of salt solution may ultimately get deposited in the soil to create other problems. Since no single agent is able to control this weed, perhaps with such a prolific and aggressive weed this should come as no surprise. It is still considered however that the long term solution will lie in releasing a guild of specific agents in orderto hit as many of the plants organs as possible and thus gradually reduce the weed vigour overtime. In view of the urgency to develop suitable alternatives / supplements to chemical weedicides for control of this noxious weed, especially under Indian conditions, where the pesticides are not only non-judiciously and indiscriminately applied but are also expensive, development of suitable IPWM (Integrated *Parthenium* Weed Management) strategy is of paramount importance.

It, therefore, appears logical that the studies proposed herein are taken up immediately to generate feasibility data under Indian context. It is hoped that the results obtained from present studies will help in generating appropriate data to formulate suitable IPWM strategies for controlling this hazardous weed.

Taking the aforesaid views in due consideration, the present study "An investigation on the effect of environment complex on *Parthenium*

hysterophorus L., its adaptive strategies and management through non-chemical practices" was undertaken with the following aims and objectives.

1. To study the habit of *Parthenium hysterophorus* and to assess its harmfull effects against crops, animals and humans.

2. To investigate various adaptive mechanisms with special emphasis on seed production, viability, dormancy, germination and polymorphism, if any.

3. To evaluate and assess their various morphological and physiological characteristics helpful for better survival.

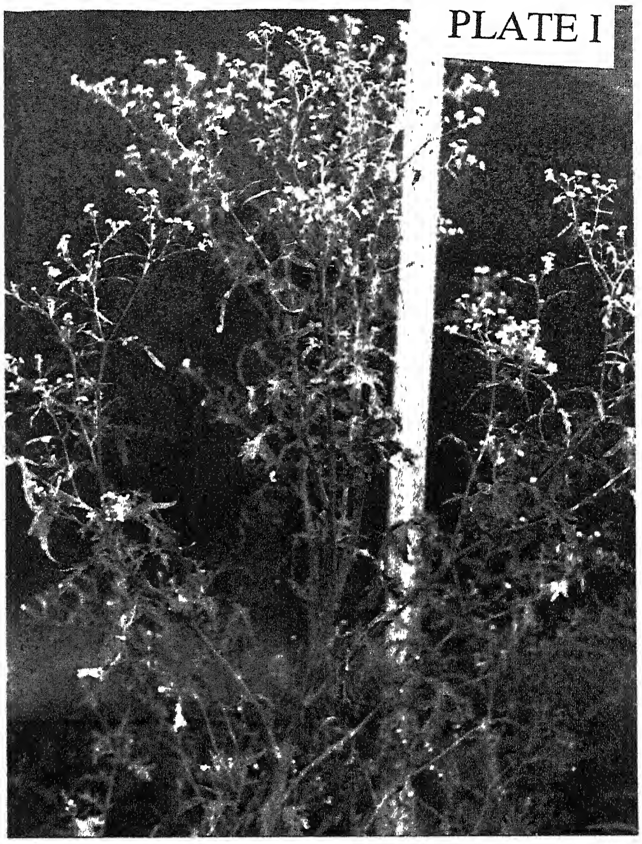
4. To study the plant soil interaction and their water economy under different soil conditions.

5. To evaluate various management practices with special emphasis on its biological control viz. using fungal species, other plants as competitors and biopesticides.

6. To improve the activity of the herbicide in combination with adjuvants or bio pesticides and also to minimise the quantity of chemical herbicides.

PLATE I

a



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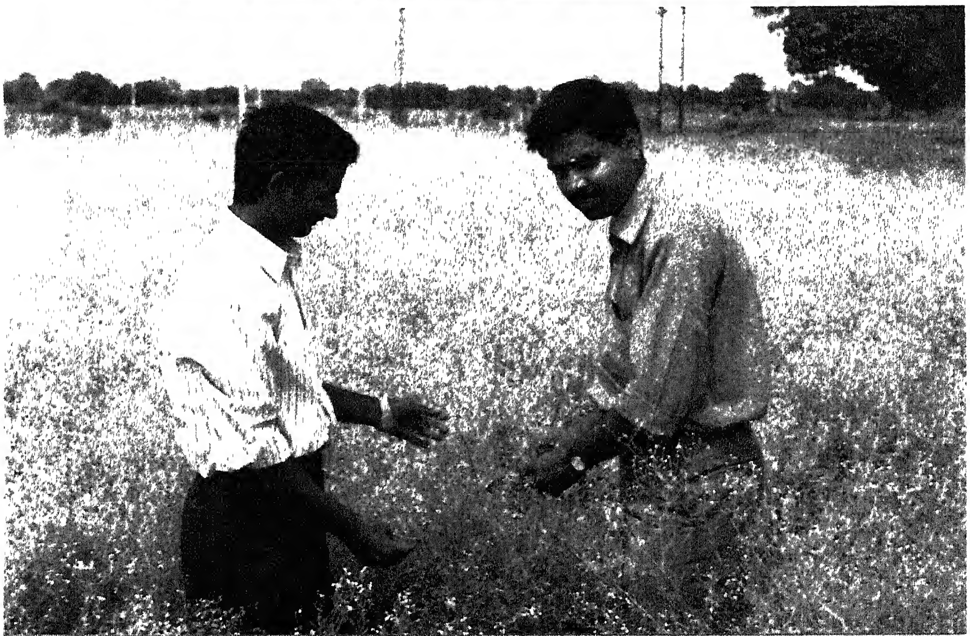

c

PLATE II

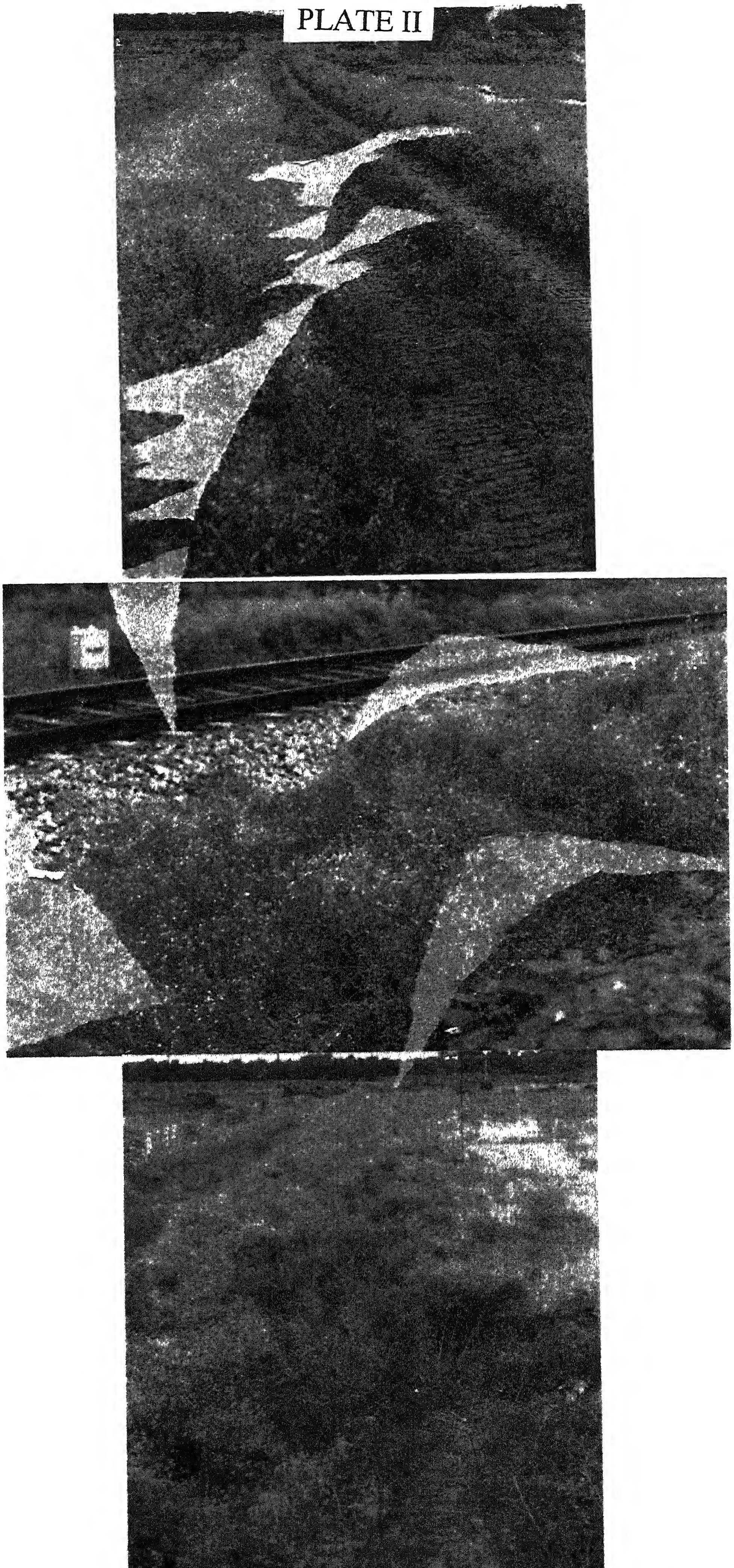

PLATE III

a

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d

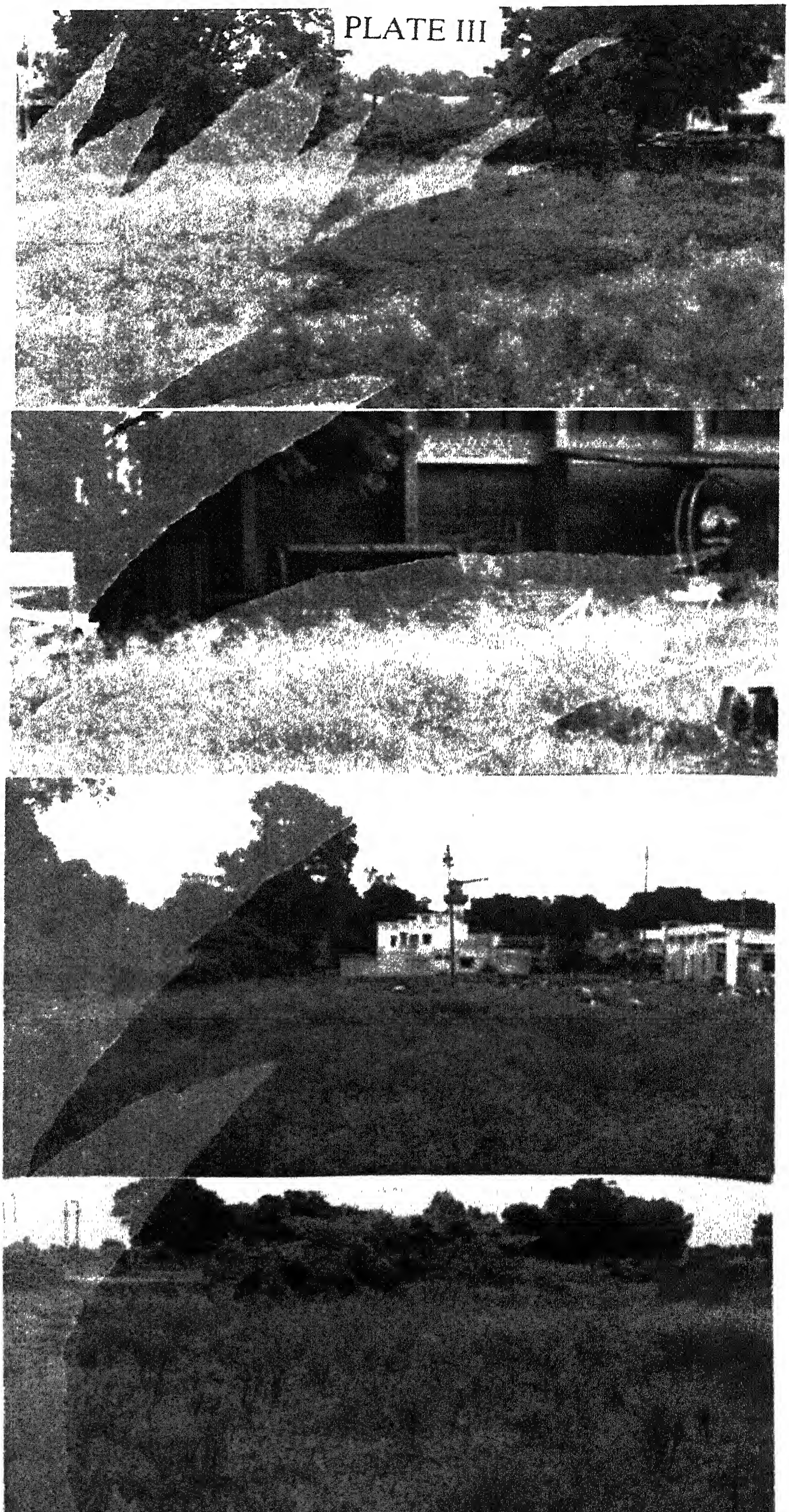
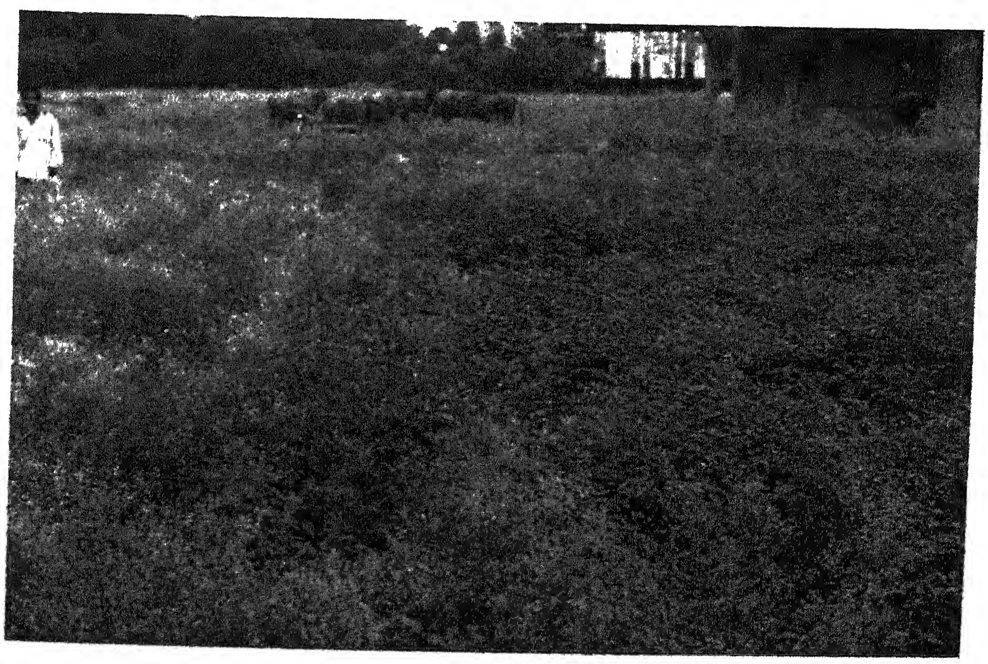


PLATE IV

a

b



CHAPTER – II

REVIEW

OF

LITERATURE

REVIEW OF LITERATURE

Parthenium hysterophorus L. a herb belonging to the family Compositeae. (Asteraceae) has attracted the attention of people around the world as poisonous, pernicious, problematic, allergic and aggressive weed which apart from posing serious human health hazards also causes allergic dermatitis and respiratory ailments. It was accidentally introduced into India through wheat imports from USA during 1950 and since then has spread phenomenally throughout the length and breadth of the country. In U.P. it has spread almost in all parts including cities like Lucknow & Allahabad. Noticed earlier as a stray weed on bunds, water canals, waste and marginal lands it has lately invaded agricultural lands particularly the range lands, forests, vineyards, orchards and poorly managed arable fields causing yield reduction to the tune of 40% in agricultural crops and upto 90% in forage production in grasslands. Production of large number of seeds (10,000-15,000/plant), small and light in weight for easy and widespread dispersal, adaptability to adverse environmental conditions and ability to suppress local flora by allelopathic effect, make this weed to flourish and spread luxuriantly.

What is more concerning with regard to *Parthenium* is its effect on human and animal health. In a sample survey conducted at Bangalore, it was recorded that 70% of the population suffered from allergic rhinitis due to *Parthenium* pollen and 47% suffered from nasobronchial allergies. Unfortunately, there is no effective treatment for dermatitis, other than exclusion of the weed. Severe cases can lead to infection, septicaemia and

even death. The weed is also a potential health hazard to the cattle causing several medical complications, thereby reducing the milk yield.

Lieth, 1974, stressed the relationship between the phenology of plants and the process of primary production, and asserted that "complete success in ecosystem modelling could never be achieved without the incorporation of phenology and seasonality consideration".

Turner and Vollmer 1982 commented on conspectus growing side by side in natural situations but distinctly out of phase in the timing and intensity of various life history events. Whether these differences reflected genetic variability or subtle microgeographic differences in soil conditions is not known.

Variability in seed size, weight, shape and colour are myriad and are important in seed identification. Among the most significant factors by which natural relation can guide the direction of evolution in higher plants are thus vigour of establishment of the seedlings in new locations (**Stebbins,1976**).

The importance of seed size in relation to survival of seedlings in variety of environments was first realized By **Salisbury (1942)**. The variations in seed size and weight may be controlled by one or two factors. Competition for food during embryo development and seed maturation among seeds of the same individuals and seeds in the same fruits as a factor of seed size. Viability has already been suggested by **Salisbury (1942)**.

Porter, 1949 has suggested that a seed shall be considered to have germinated when it has developed those structures that are essential for a normal seedling.

Mayer, 1953, defined germination as that group of processes, which bring about sudden transformation of dry seed into the young seedling.

Distribution of many species is influenced by the germinability of seeds (**Went, 1957**).

The effects of environment on seed germimation are quite complex because of factor-interactions and intrinsic physiological requirements (**Noggle & Fritz, 1977**).

The epidermis of plant organs is often ornamented with outgrowth called trichomes or hairs. Essentially all the major groups of terrestial plants appear to have or had the capacity to develop such structures. These hairs have been repeatedly linked either directly or indirectly to increased water use efficiency (**Fritsch & Salisbury 1965**).

A layer of hairs will in most cases decrease the air movement next to the leaf, and thus creates a greater thickness of still air through which water vapour must diffuse in moving from the saturated leaf interior to the drier air outside (**Woolley, 1964**).

According to **Hall and Schulze 1980** control systems are present in plants which are responsible for diverse responses of stomata to environment and which result in integrated and adaptive functioning.

Most of the factors that effect photosynthesis and water relations in leaves also influence stomatal movement since the opening of stomata depends primarily on an uptake of water by guard cells it is understandable that severe water stress will inhibit stomatal opening **(Zelitch, 1969)**.
Stomatal opening depends on an increase in turgor in the guard cells , thus the difference between the osmotic value in the two neighbouring cells, determines the degree of stomatal opening as has been emphasized by**Heath (1959)**. **Stalfelt (1966)**; **Glinka (1971)**; and **Bhandari et al (1974)**. **Sen *et. al*.. (1972b)** and **Bhandari *et. al*.. (1974)**, explained the stomatal mechanism in terms of reversible starch sugar changes.

A stomatal characteristic that has been used considerably to indicate the capacity of leaves to withstand water stress is the speed of stomatal closure in detached leaves and the steady rate of waterloos from leaves with closed stomata **Stalfelt, 1929** and **Pisek**.

Because the stomata regulate the bulk of water loss from leaves, it might be expected that stomatal adaptations with in species that effect both the quantity and patterns of water loss would be fairly common. Such stomatal adaptations involve reductions in the number and/or size of stomata, alterations in leaf morphology so that stomata are recessed in to crypts so as to increase diffusion resistance to vapour, transfer, and alterations in stomatal response to environment or internal water stress resulting in water conservation **(Pallardy, 1981)**.

Crafts, 1968, has advocated that the plant water deficit originating from low soil water potential or high transpiration demand has consequences for all

the physiological functions ranging from primary bio-chemical process to overall growth and development.

Species with smaller changes in relative water content for each interval of water potential is considered to be drought resistant (**Javis, 1967; Connor & Tanstall, 1968**).

The relationship between the relative water content and water potential of leaves measures the amount of water held by the leaf tissues and varies considerably according to type and age of the plant and growing conditions (**Slatyer, 1960; Knipling, 1967; Pospisilova, 1973**)

The water potential of leaf determines in part, the water gradient between soil and leaf and between leaf and environment (**Scholander *et. al.*; 1964; MacBryde *et. al.*; 1971**).

Sveshnikova 1973, studied leaf water content during different month and suggested that it does not necessarily due to physiological changes.

Jankovic & Popovic, 1972 studied the water content in the leaves of some significant herbaceous plants and found that water content varied both diurnally and seasonally. However the daily variations were less significant that the seasonal ones.

Shreve (1951), noted in desert that height and bulk are chiefly determined by the soil moisture availability during the growth period; and in winter ephemerals by the amount of warm and sunny days following the rainy periods.

According to **Sveshnikova, 1973**, among many factors which run counter to the natural establishment soil moisture conditions perhaps play the most significant role for growth and development of plants.

Kramer, 1980, opined that plants growing under stress condition exhibit drastic reduction in photosynthesis and disturbance of many other vital physiological processes.

Life has evolved in water, and water remains the essental medium in which bio-chemical processes when provided with water, if it dries art, it does not necessarily die, but it must at least enter the antibiotic state in which all the vital processes are suspended (**Larcher, 1983**).

The water status of plant tissues depends on (i) resistance to flow of water in the soil, which varies with water content, (ii) resistance to flow from within the roots and other tissues of plants, which depends on physiological factors. It is thus, not possible to predict water statusof a plant from condition in the soil or the atmosphere alone and it is not possible for a plant to wilt with abundant water in soil and to remain turgid when the soil is relatively dry (**Gardner, 1964**).

Carbohydrates are essentially synthesized by the green plants from water and atmospheric carbon dioxide. They are important in several ways, especially as means for the storage of energy trapped from sunlight in the process of photosynthesis and support tissues of plants enabling them to achieve erect growth, and for providing the carbon skeleton for other synthetic processes. Bio-chemical aspects of water stress have been reviewed by **Levitt (1972)** and *Kozlowski (1972)* Water stress causes significant changes in the kinds and amount of carbohydrates in plants

Sharples & Burkhart 1954, mentioned that carbohydrates get influenced by various environmental factors and growth activity of plants. Plants that drastically reduce their metabolic activities below their compensation point will have low carbohydrates need and therefore a greater tolerance to lowest assimilation rates than do plants that are without this mechanism (**Singh,1966**). The carbohydrates contents decreased under the influence of water stress (**Brix, 1962; Thakur and Rai, 1980**). It has been pointed out that leaves of plants subjected to water stress often show decrease in starch content which is usually fallowed by an increase in sugar content (**Levitt, 1956**). However, the sugar content does not increase in all the species. Over a period of time reduced starch, sugars, and total carbohydrates in beans and tomato.

Iljin (1929), compared the sugar contents of different species from the localities of varying degrees of dryness and discovered that in all the case individual plants of dry localities showed higher sugar content.

Amer and Williams (1957-1958), observed that plants cultivated under dry conditions gave after rewatering, a large increase in carbohydrates concentration and the amount of sugars was much higher (on a unit weight basis) than that of the leaves grown under moist conditions. The changes in proportions of sugar and polysaccharides have been related to changes in enzyme activity.

Protein are substrates of the first order in the metabolism of every organism. They differ, atleast in elementary composition from other organic compounds occurring in plants that in addition to carbon, hydrogen and oxygen, they also contain nitrogen. Proteins are made up of amino acids,

acting as building blocks. Amino acids are derivatives of the carboxylic acid in which a hydrogen atom in the carbon chain has been replaced by amino group. The amino group may occupy or position, and there may also be two or more amino groups present in chains.

It has been reported that considerable hydrolysis of proteins occurs in water stressed plants and is accompanied by an increase in amino acids (**Barnett & Naylor, 1966; Chen, 1964; Chibnall, 1954; Mothes, 1956; Petric & Wood, 1938**). The level and state of water serve as medium and structural component for proteins. Alternation of hydrature should influence the configuration and activity of enzymes leading to appreciable change in metabolic patterns (**Klotz, 1958**). Moisture stress at a particular physiological stage has a definite relation to nitrogen content of the plant. The alternation in nitrogen metabolism is largely influenced by tissue hydration. In a study it was observed that in the initial stage of tissue hydration an increased accumulation of soluble nitrogen content was due to decrease in protein synthesis. Moisture stress leads to accumulation of soluble nitrogen compounds with a concomitant decrease in protein contents (**Stocker; 1960**).

The chlorophylls are green magnesium containing proteins. The most important photosynthetic pigment in all plants is chlorophyll which is also called principal pigment. The principal pigment is one which is directly involved in the chemistry of the action whereas the accessory pigment in each system absorbs radiant energy and transfer it to the principal pigment as an energy sink (**Smith & French, 1963**).

A good extraction procedure should result in little or no change in the pigments being extracted. Acetone is a solvent that is usually preferred in the extraction of chlorophyll. The light absorption spectrophotometric determination of chlorophyll is done to determine the concentration of total chlorophyll and of chlorophylls a and b in the mixture (Halden, 1965).

REVIEW OF CURRENT STATUS OF RESEARCH & DEVELOPMENT IN INDIA

Weedicides like paraquat, monosodium methane arsenate, disodium methane arsenate, atrazine, 2, 4-D sodium salt, bromacil glyphosate or sodium chloride in recommended dosage have been tried in India with variable success. In India, a total number of 25 fungal species were isolated and identified from *Parthenium* the majority being opportunistic nectrotrophs. *Myrothecium roridum* Tode ex Fr. appeared from the field survey and subsequent pathogenicity tests, having good potential for mycoherbicide development. From further pathogenicity screening of the other fungi, it was observed that a few could effectively kill mature plants including *Colletotrichum gloeosporiodes* (Penz) suc., *Fusarium oxysporum* Schlech, *Fusarium moliniforme* Sheld in addition to *Myrothecium roridium.* The two soil borne *Fusarium* spp were the subject of a later study and it was considered that although their biological control potential was high, their safety and specificity remained to be evaluated. In Haryana, *Curvularia lunata* is reported to produce leaf spot disease on *Parthenium.* Other workers in India are pursuing similar lines of research, but so far no formulated product appears to have reached the field testing.

Some work on antagonistic competitor plants has also been done in India. Plants like *Abutilon indicum, Cassia sericea, C. uniflora, C. occidentalis, Croton sparciflorus, Tagetes erecta, Ipomoea carnes, Mirabilis*

jalapa, Sida spinosa and Tephrosia purpurea have been used for controlling *Parthenium* with limited and variable success.

ABROAD

The neotropical compositae, *Parthenium hysterophorus,* has achieved major weed status in India and Australia within the past few decades. In the sequel noxious weeds of Australia (1992) *P. hysterophorus* merits five pages. It is thus that *Parthenium* weed has come to the force in the last 20 years, based mainly on its rapid spread in both Australia and India. In addition, recent studies from Israel (1986), Taiwan (1988), Nepal (1991) and Ethiopia (1992) suggest that *Parthenium* weed is still spreading and may become prominent in other parts of world in near future. The weed can affect crop production, animal husbandry, human health and biodiversity. Entomological survey and the screening of selected arthropods were undertaken both in Brazil/Argentina (1977-78) and Mexico (1978-83) by both Queensland Department of Lands and Commonwealth Institute for Biological Control. Severe damage to *Parthenium* was noted rarely in 1995 during North America surveys. Over 260 phytophagous arthropods species were collected from *Parthenium* although only 144 actually fed on the plant. After preliminary screening in Mexico and final evaluation in quarantine in Australia, five oligophagous or monophagous species were released in Queensland in the 1980s. The *Zygogramma* beetle showed considerable promise initially but was short lived as the beetle probably failed to adjust to the variable rainfall pattern.

Rust strains were collected in Mexico and assessed in the U.K. for pathogenicity to the Australian weed biotype based on sporulation capacity and host damage. Rust infection by *Puccinia abrupta* var. *parthenicola* and *P. melampodi* hastened leaf senescene, significantly decreased the life span and dry weight of *Parthenium* and reduction in flower production by 90% during 1989-94. The white smut, *Entyloma pathenii* Sydow, collected in

Mexico and Argentina, also shows promise in the field. The Biological Control Programme against *Parthenium* is still active in Australia, eight insect and one fungal species have been released in Queensland but, so far, no dramatic returns have been forthcoming.

Studies conducted by **Dhopte and Holey 1990,** during kharif exhibited a few abnormal *P. hysterophorus* plants having excessive branching, shortened internodes, greatly reduced leaf size and transformation of florets in phylloid structures in a field in a city area. The field was infested with this weed over an area of about 0.25 ha, but the incidence was meagre. *Parthenium* plants growing around affected plants were normal. Preliminary studies revealed floral transformations of calyx and corolla into leaf like structures. There was no seed formation in infested plants. The possibility of biological control of *Parthenium* by induction of phyllody using vectors of the pathogen responsible for this phyllody is discussed.

According to **Joshi, 1992,** *C. uniflora,* leguminous shrub of some economic value, replaced *P. hysterophorus* by >90% in an area of 4800 M^2 over a period of 5 years. While leachates from the germinating seeds hampered the establishment of the summer generation of *P. hysterophorus* due to allelopathy, the robust colonies of *C. uniflora* prevented the establishment of the winter of *P. hysterophorus* below them. *C. uniflora* is dispersed slowly to neighbouring places through rainwater sustained efforts to introduce *C. uniflora* offer considerable promise for *P. hysterophorus* control.

Land care, which at best means people voluntarily adopting management that preserves and rebuilds the land resource is a major

development in land management in Australia. The stimulus to form the Mount Abundance Landcare Group in Queensland grew from a concerted programme to control *Parthenium* weed. The landholders recognized that the longer term problems of soil erosion, declining productivity of pastures, feral and native animals, and salinity required sustained effort. Whereas the extent of the concerned community was in this case clear, there is a vast of Australia where the producers are too thinly spread to engage in group action. While informed people have sounded warnings for a decade, the upsurge of interest and its translation into action has all taken place within the last two years. Eighty five percent of producers will eventually change their management to improve and sustain productivity while 15% currently don't care about the issue. Such rugged individualists may finally be persuaded when majority in their community have shown the outstanding result that can be achieved **(Douglas et. al. 1992)**.

According to **Joshi, 1992,** the biological control of *P. hysterophorus*, in India, by using the allelopathic effects of *Cassia uniflora* are discussed. Descriptions of the life cycles of both species and economic and other advantages of utilizing *C. uniflora* are also included.

Studies conducted by **Malabika et. al., 1992,** after an introduction, 34 papers are presented on various aspects of environmental protection. The papers were originally presented at a national seminar held in 1987 or 1988, but have been largely revised and updated. Many of the papers discuss environmental protection in India in relation to forest management planning, deforestation, afforestation and silviculture. Other aspects covered are: wildlife and environmental improvement; pollution and afforestation, bioindicators or pollution, plant damage by pollution, potable water quality,

environmental pollution and viral hepatitis, and pollution tolerance of aquatic plants; watershed management, hydrology and afforestation; conservation of germplasm and endangered plant species, weed control (of *Parthenium*); mathematical *modelling* for environmental protection; cultivation of plants in saline soils; culture of spirulina platensis (a blue green alga) on industrial waste for biomass production; fruiting and hyphal structure of wood decay fungi under different environmental conditions (mesophytic and xerophytic); and polymorhism (in heterochromatin and glucose 6 phosphate dehydrogenase) in the ethnic population of NE Himalaya.

According to **Mahadevappa et. al., 1992,** in the 1987 rainy season, *P. hysterophorus* plants were manually removed from 3 waste land sites in Bangalore before the sites were sown with *C. sericea.* The size of *C. sericea* increased with time relative to that of *P. hysterophorus* such that, in 1989, the *P. hysterophorus C. sericea* ratios at Thindlu village, Amruthahalli and the entrance to Hebbal MRS were 1:17, 1:21 and 1:150, resp *P. hysterophorus* growth was more vigorous outwith than withing *C. sericea* colonies (F.W. of 55.42 - 102.2 vs. 27.86 - 38.8 g, DW of 17.21 - 24 vs. 7.86 8 g and 58.1 - 77.6 vs. 29.6 - 33 flower heads, resp.).

A review is given of *P. hysterophorus* with details of its biology and distribution in Asia, Africa and Australia, allergic eczematous contact dermatitis (AECD) it causes in man, the sesquiterpene lactones in *Parthenium* and their mechanism of toxicity, allergic rhinitis in man due to *Parthenium* and its cross reactivity to other specieis of composites, toxicity of *Parthenium* to animals and possibilities for its biological control. **(Towers et. al., 1992).**

According to **Pitt, 1992,** the following aspects of *P. hysterophorus* are briefly discussed; its identification (including a line drawing), its introduction, distribution and spread in Australia (in particular, in the Northern Territory), aspects of its ecology that contribute to its success as a weed, its nuisance value (including the allergic reaction it causes in some people), means of preventing its spread and of controlling it by physical, cultural, chemical and biological methods.

The main weed problem in the tropics and subtropics, (*Cyperus rotundus, Striga* spp., *Orobanche* spp., *Sorghum halepense, Rottboellia cochinchinensis, Imperata cylindrica, Cynodon dactylon, chromolaena odorata* (Eupatorium odoratum), *Parthenium hysterophorus, Eichhornia crassipes and Salvinia* spp.), and the methods available for their control at a small scale farming level are reviewed. It is suggested that programme be implemented at a national or regional level for management of these weeds, having components of applied research, extension of research outcomes and training activities, with education of the farmers on economically feasible measures of control. All these programme require strong financial support from the donor agencies **(Labrada, 1992)**

Studies conducted by **McFadyen, 1992,** On *Parthenium* weed its biology and distribution, and the problems it causes in Australia, India and elsewhere are described. A biological control programme involving the introduction of insects from the Americas started in Australia in 1975 and is still in progress. Six species of insects have been released, of which four are established but only one, the moth *Epiblema strenuana*, is exerting significant control on the weed. The moth larvae form galis in the *Parthenium* stems and shoots; damage by several larvae stunts plants and

reduces seed production. Unfortunately, the erratic climate interferes with control; long dry periods reduce the moth population to very low levels so that when *Parthenium* germinates after rain there is inadequate control. Efforts to establish other biocontrol agents are continuing in Australia. India rejected *E. strenuana* because of attack on *Guizotia absyinnica* in tests, but had successfully established the leaf feeding chrysomelid *Zygogramma bicolorata* with promising results. Other insects evaluated in Australia are available and should be tested for use in India and other countries with a *Parthenium* problem.

Field studies were carried out in Allahabad, Uttar Pradesh, during 1989, to assess the effects of applications of 10, 20 or 30% solutions of sodium chloride, 0.5 kg/ha 2, 4 -D (Sodium salt), both treatments combined or handweeding (HW) for control of *P. hysterophorus* in wheat cv. Sonalika. Sodium chloride was slightly phytotoxice to wheat; it scorched the leaf tips margins. The degree of phytotoxicity of sodium chloride to P. hysterophorus increased with increasing sodium chloride concn. The 10% solution severely scorched weed foliage, whereas 20 and 30% solutions burnt the leaves. Application of 2, 4-D was slightly toxic to *P. hysterophorus.* Both treatments combined gave better control of *P. hysterophorus* than sodium chloride alone. Populations of *Chenopodium album* were lower after 2, 4-D, 2, 4-D + sodium chloride treatments. Sodium chloride was not effective for controlling *Cyprus rotundus*. Highest wheat yields were obtained with 10% sodium chloride followed by 2, 4-D **(Sarkar, 1992).**

According to **Singh, 1993,** *Parthenium hysterophorus* is an exotic noxious weed of India and causes serious health problems in susceptible human beings and cattle. Integrated measures adopted to control *P.*

hysterophorus are discussed, including physical control (manual uprooting), chemical control (using e.g. post-em. Fernoxone (2, 4-D) at 5.0 kg/ha), competitive plants (*Cassia uniflora* in Karnataka), and biological control using *Zygogramma bicolorata.* (leaf -feeding chrysomelid). The bioecology of *Z. bicolorata*, its host specificity and importation, the development of its rearing techniques, its release and its spread onto sunflowers is also document.

Parthenium hysterophorus is a native of Central America which has become a problem weed of Australian rangeland since its accidental introduction in 1958. Investigations of potential pathogens for classical introduction were begun in 1983 in order to supplement insect biological control. An evaluation was made of the biology and host range of two autoecious rust fungi, *Puccinia melampodii* and *P. abrupta* var. *partheniicola* which were collected in NE Mexico. Preliminary studies showed that *P. melampodii* had an unacceptably wide host range and hence this rust has been rejected as a biological control agent. *P. abrupta* var. *parthenilcola* had a narrow host range and caused severe damage to *Parthenium* weed. Infection with this rust hastens leaf senescence and significantly reduces the life cycle and DW of plants. Also the production of mature, seed-bearing flowers is reduced 10-fold on diseased plants. Thus *P. abrupta* var. partheniicola appears to be a promising biological control agent for *Parthenium* weed **(Parker, 1993).**

According to **Jayanth and Bali, 1994,** *Zygogramma bicolorata*, a chrysomelid introduced into India as a biological control agent against the weed *Parthenium hysterophorus,* was capable of breeding in the loboratory at constant temperatures ranging from 15to 35xc. The temperature range 20-

30 xc was the most suitable, development taking 46.6-20.75 days. Eggs failed to hatch at 40^0C. and only 4 and 16/ hatching took place at 15 and 35 xc, resp. Diapausing adults in the soil tolerated continuous exposure to 40 and 45^0C for only 10 days and 21h, resp. This suggests that the beetle is unlikely to survive in a state of diapauses in parts of the country where the temperature exceeds 45 ^{0}C in summer.

Studies conducted by **Chippendale and Panetta, 1994.** in Queensland, the *Parthenium* weed commonly dominates cultivated and other disturbed areas, as well as flood-prone pastures. In 1990-91, a mail survey was conducted on beef producers in the most heavily infested regions in central Queensland. Annual losses were due to reduced livestock numbers, reduced live wt gains and weed control costs. The effects of *P. hysterophorus* on human health are also discussed. The costs of research into *P. hysterophorus* control are noted.

According to **Channappagoudar et. al. 1994,** in field trials conducted at the Water Managment Research Station, Belvatgi (Karnataka), during rabi 1979-80, the competitive ability of *Parthenium hysterophorus* and other weeds in sorghum cv. CSH-8R, and the effects of weed competition on crop yields components, were evaluated. The effects of pre-em. atrazine at 2.5kg /ha and terbutryn at 1.0kg, and of post em. 2, 4D at 2.5 kg (applied 3 weeks after sowing) on crop yields were also evaluated. The presence of *P. hysterophorus* and weeds other than *P. hysterophorus* reduced sorghum grains yields from weed free control values of 6.47 t/ha to 4.25 ad 5.2 t, resp., and reduced sorghum 1000 grain wt from 38.9 g to 26.6 and 74.9g, resp. Atrazine, terbutryn and 2, 4-D resulted in sorghum grain yields of 6.44, 6.2 and 5.93t, resp., and 1000 grain wt of 38.73, 38.1 and 35.45 g, respectively.

Hot and cold extracts of *P. hysterophorus* (Asteraceae) were tested against larvae of *Culex quinquefasciatus* in the laboratory. In the undiluted cold extract, 100% of Ist and 2nd instar larvae died, whereas only 85% of 3rd and 4th instar larvae succumbed. There was no mortality in 50 and 80% cold extracts. Ist, 2nd, 3rd and 4th instar larvae all succumbed in the undiluted hot extract (after cooling). In the 50% hot extract, 100% of Ist and 2nd instar larvae died, with 60 and 40% mortality in 3rd and 4th instar larvae, respectively. Although extracts of this weed show good larvicidal properties, the authors point out that care should be exercised in its use as some people are allergic to it **(Dwarakanath, *et. al.* 1994).**

The 2nd meeting of the Fact Finding Committee on *Parthenium* was held in India in 1993. This report of the meeting is concerned mainly with the use of *Zygogramma bicolorata* as a biological control agent against the weed *Parthenium hysterophorus* in India and reportes of the chrysomolid on sunflowers in India.The results are discussed of laboratory and field studies on host specificity and the screening of sunflower varieties, presence (and fooding) by the chrysomolid on several species of wæds; the taxonomy and identity of the chrysomolid; phagostimulant and antifeedant studies; current status of Z. *bicolorata*; and future programme. It is concluded that in spite of the abundance of *Z. bicolorata* adults in close proximity to sunflower fields and the presence of a few adults on sunflower plants, there has been no feeding on sunflower crops in Karnataka, Maharashtra, Tamil Nadu, Andhra Pradesh or Kerala **(Indian Council of Agricultural Research, India, 1994).**

According to **Rani and Kohli, 1993,** with increasing concentration, both the herbicide glyphosate and the allelopathin parthenin gradually lowered leaf water content of *Parthenium hysterophorus* and *Phaseolus aureus* (*Vigna radiata*) and increased DM content. When chlorophyll content was related to leaf FW, chlorophyll content apparently increased

with increasing active substance concentration. The opposite conclusion which reflected that observed visually, was obtained only when the results were related to DM.

In some parts of Karnataka and Maharashtra states in India, *C. uniflora*, a leguminous understorcy shrub, has effectively replaced the problematic weed, *P. hysterophorus*. Laboratory studies revealed that phenolic leachates from different parts of *C. uniflora*, especially from germinating seeds, significantly inhibited the germination of *P. hysterophorus* seeds and retarded the growth of seedlings from successfully germinated seeds. In field trials in 1986, seedlings of *C. uniflora* outcompeted the seedlings of the previous summer generation of *P. hysterophrus*, causing reductions in height, DW and the number of inflorescences of the latter, so resulting in the reduction of their seed production. Because of its longer life spac, *C. uniflora* also effectively prevented the establishment of winter generations of *P. hysterophorus* plants in its area of growth **(Joshi, 1994).**

AQIS (Australian Quarantine and Inspection Service) had approved the release from quarantine of a stem galling weevil, *Conotrachelus* sp. su. QDL 014, as a biological agent to assist in the control of *Parthenium hysterophorus*. The weed, an invasive annual of open land and pastures, occurs in Queensland, New South Wales and the Northern Territory. *P. hysteropherus* is capable of growing in all states but, while it can be a serious pest in warmer regions, it is unlikely to become a major problem in winter rainfall districts. Since 1979, 7 other species of insects and a rust disease have been released in attempts to control *P. hysterophorus*. A moth, *Epiblema strenuana*, has reached damaging levels, with its larvae feeding

internally in the weed's stems to form gall, giving some control. A beetle, *Zygogramma bicolorata*, caused moderate to severe damage to *P. hysterophorus* at distances up to 50 km from 1 of its release sites, but otherwise has had little effect **(Aqis bulletin, 1994).**

Studies conducted by **Pandey et. al., 1993,** the control of *P. hysterophorus* using a new collar rot disease caused by *S. rolfsii* is discussed. The symptoms of the infection are described. Results obtained in greenhouse and field trials showed that inoculation with *C. rolfsi* caused 90-95% and 35-40% mortality, resp., in *P. hysterophorus* seedlings.

A survey was conducted in 1989 at Karnataka and the surrounding area of Yellamma Temple, *Parthenium hysterophorus* was found at high densities in and around the cities, towns and villages of the areas surveyed. *Cassia occidentalis, Croton sparsitilorus, Cassia tora, Tephrosia purpurea, Cassia auriclata* and *Cassia serica* were also observed in the areas infested with *P. hysterophorus*, due to their allelopathic effects on *P. hysterophorus*, these species are highlighted as possible biological control agents of the weed **(Mamatha and Mahadevappa, 1993).**

According to **Grittiths and McFadyen, 1993,** *Platphlonidia mystica* was studied as a potential biological control agent of the weed, *Parthenium hysterophorus*. During host specificity testing, larval feeding damage occurred on sunflower and to a lesser extent on Dahlia sp., but the risk of damage to sunflowers under field cage conditions was considered negligible. In view of the very great problem that *P. hysterophorus* was causing, and the threat of its continued southerly spread into Southern Queensland, New

South Wales and Victoria, field release of *P. mystica* was authorised and commenced in Queensland in late 1992.

Laboratory experiments revealed that leaf extracts of *P. hystrophorus* greatly inhibited the growth of *Epidermophyton floccosum* (90.52%), *Trichophyton rubrum* (82.68%) and *Microsporum gypseum* (80%), moderate inhibition was observed in *Trichophyton mentagrophytes* (75.5%) and *Aspergillus flavus* (70.2%), and the min. inhibition was demonstrated against *Rhizopus oryzae* (55.62%) **(Rai, 1993).**

As per **Bockott et. al., 1993,** seedlings of the guayule cultivar W10 were grown singly in sand in 2100 cm pots, in a phytotron. In the first of 2 experiments, they were supplied with Hoagland's nutrient solution containing all micronutrients (Control), no micronutrients, or all except one of the following : B, Cu, Fe, Mn, Mo or Zn. In the second experiment, the nutrient solution was adjusted to contain 0, 6, 12, 23, 46 (Standard Hoagland's solution), 93, 186 or 464 MB. The first experiment began in Aug., with 2 flowering flushes peaking in Oct. and Feb., and ended in Mar. The seeds from these plants were tested for germination (after soaking in water for 4 h, followed by 0.25% NaCl for 1 h and finally 200 mg GA_3+7/litre). The results showed that a deficiency of B, but of no other trace element, significantly reduced the plant growth, seed production and percentage seed germination. The optimum concentration of B for seed production was between 20 and 100m.

In field trials at Hawkes Bay in 1991-92, 3 medicinal herbs feverfew (*Tanacetum Parthenium*) valerian (*Valeriana officinalis*) and coneflower (*Echinacea purpurea*) were tested for their tolerance to a range of herbicides applied both pre-transplanting and over established plants. The herbicide tested were Trifluralin (1 kg/ha), Chlorpropham (2-6kg), Diuron (1.5 - 2 kg),

Pendimethalin (1.5-2kg), Propyzamide (1.5 kg), Simazine (3-4 kg), Terbacil (1 kg), Oryzalin (2kg), Oxadiazon 1.6 kg and Paraquat (0.5kg). Feverfow showed good tolerance to Pendemethalin, Oryzalin and Oxadiazon at planting and to Terbacil when established. Valerian tolerated Pendimethalin, Oryzalin and Trifluralin at planting, and Terbacil and Diuron when established. Concflower tolerated Pendimethalin, Oryzalin and a combination of Oryzalin and Chloropropham at planting and Terbacil, Diuron and Chlorpropham when established. Pendimethalin, Oryzaln + Chloropropham and Terbacil gave the most effective control of the most common weeds, *Solanum nigrum* and *Ueronica persica.* (Hartley M.J., 1994).

According to **Narayana et. al., 1995** cold and hot water leaf extracts of 25 plant species comprising horticultural crops (including multipurpose trees), weeds, forage crops and medicinal plants at 5% (group I) and 30 forest tree species at 10% (group II) were tested against the Brinjal (*Solanum melongena*) damping off pathogen, *Pythium aphanidermatum* in PDA cultures. None of the leaf extracts gave complete inhibition of the pathogen. However, for group I plants, maximum inhibition was obtained with cold water extracts of *Polyalthia longifolia* (56.6%). *Desmodium purpureum* and *Mangitera indica* did not show any inhibitory effects. Among the hot wate extracts tested, *Parthenium hysterophorus* gave maximum mean inhibition of 48.3%, with *D. purpureum* the least effective (2.7%). In the group II plants cold water extracts of *Caesalpinia paucitlora* were high inhibitory (85.5%) followed by *Manilkara kauki* (78.8%). *Berrya cordifolia* did not show any inhibitory effect. Hot water leaf extracts of

Eucalyptus microtheca showed 90% inhibition, while *Spathodea campanulata* was the least effective.

The Toxic effects, biology and dispersal of *Parthenium hysterophorus* in New South wales are described and control strategies outlined. The importance of correct identification is stressed. Information on chemical control measures is given in a 1 page supplement : Atrazine and Picloram + 2, 4-D for summer crops, including *sorghum* and *maize*; 2, 4-d n *picloram* for non - legume pasture, and non-crop and industrial situations; dicamba for non-legume pasture and non-crop situations; hexazinone for industrial situations; metsulfuron methyl for winter cereals. and atrazine for fallow. Advice on appropriate mechanical and cultural pasture management practices is given. Initial attempts at biological control are outlined. The operation of a management plan is outlined and legislation regarding *P. hysterophorus* as a noxious weed is noted **(Trounce, 1995).**

Studies conducted by **Dhillon et. al., 1995,** *Parthenium*, the principal constituent of *P. hysterophorus*, and alantolactone and isoalantolactone from *I. racemosa* were transformed chemically to different products with a view to studying the stucture activity relationships for ovicidal activity against *Chilo partellus*. Among these compounds, the arranged product of parthenin with Al_2O-H_2SO_4 was the most active; this activity is attributed to the change in the carbon skeleton and extended conjugation.

A total of 15 plant extracts were evaluated in vitro tests for their fungicidal activity against *Fusarium solani*, Max. inhibition was demonstrated by *Parthenium hysterophorus* (86%), followed by *Vinca rosea* (*Catharanthus roseus*) (77%), *Prosopis julitiora* (65%), *Leucaena*

leucocephala (53%), *Gliricidia maculata* (G. sepium) (57%) and *Eucalyptus globulus* (45%). Pot culture experiments were then conducted to evaluate the activity of these 6 plant extracts against *F. solani* on brinjal (aubergines). Least wilt incidene (mean over 45 d after treatment) was demonstrated by *P. hysterophorus* (27%) followed by *C. roseus* (33%), *P. juliflora* (46%), *G. sepium* (62%) and *E. globosus* (77%). The mean incidence of wilt in control pots was 83% **(Vimala et. al., 1995)**.

According to **Jayanth, 1995,** time specific life tables were constructed for *Zygogramma bicolorata* which is a promising biological control agent of the weed *Parthenium hysterophorus* in and around Bangalore, Karnataka, India. The intertility of eggs (46.00- 71.10%) was the key mortality factor, followed by death during the pupal stage (15.76 - 21.38%), as confirmed by key mortality factor analysis and survivorship curves. No parasitoids or predators were recorded on this insect, while some of the dead pupae/pre-pupae (2.27-17-24%) were infected by *Metarhizium anisopliae*. The high generation trend values (305.88 - 557.14, gave an indication of the biotic potential of this insect, which was found to cause rapid defoliation of the weed under field conditions.

Studies conducted by **Howard et. al., 1995,** extracts of 26 plants were evaluated for their toxicity to the slug *Sarasinula plebeia* in the laboratory. The extracts were applied to bean *Phaseolus* leaves and incorporated in pellets. The following showed repellent activity : aqueous extracts of *Nerium oleander* and *Thevetia peruviana*; aqueous extract and active principle of *Solanum globiferum*; and ether extracts of *Parthenium hysterophorus*.

Zygogramma bicolorata, a chrysomelid of Mexican origin, released in Bangalore, India, in 1984, was observed defoliating *Parthenium hysterophorus* in 1988, and had dispersed over 50000 km^2 by 1992. The insect appears to have potential in reducing weed density in those parts of India having moderate weather conditions **(Jayanth et. al., 1995).**

According to **Narasimhan et. al., 1995,** after ensilage, the toxic compositae weed *Parthenium hysterophorus* was devoid of the toxic principle parthenin. Laboratory scale ensilage indicated that no parthenin was detectable after 5 weeks of anaerobic fermentation. for animal feeding studies, silage was made on a large scale from *Parthenium* alone or mixed with maize. Crossbred bull calves and buffalo bull calves were fed for 12 weeks on a control diet or diets containing *Parthenium* silages. The animals ate both *Parthenium* silages and body weight gains were similar to those of the controls. Digestibilities of DM, fibre and nitrogen free extract were greater with the control diet, but the biological value of proteins tended to be greater with the *Parthenium* silage containing diets. Haematological studies indicated no significant differences between experimental and control groups in selected parameters, except for a reduction in blood urea nitrogen in the animals fed on *Parthenium* silage. The possible causes for these biochemical alterations are discussed. Since the nutritive value of *Parthenium* silage compares favourabley with the standard diet, and *Parthenium* seeds collected from the silage did not germinate, it is suggested that ensilage can be used as an additional method in the containment and eradication of these plants, which grow wild in India.

Studies conducted by **Ojeda and Trione, 1995,** the growth retardant CCC (chlormequat) supplied as a soil drench to young guayule plants at

rates of 250, 500 or 1000 ppm increased the following growth characteristics : plant height, length and diameter of main and secondary stems; number of leaves and leaf area, number of peduncles on main shoot of infloεscences; number of capitula per peduncle and total DM. Growth was sustained for longer than in control plants. In addition, there was a significant increase both in the concentration of organic N in stems and leaves, and in the absolute N content in all plant organs. Leaf chlorophyll content was also higher than that in the control. The percentage of rubber and resin in the stems and roots was not modified by CC, but their absolute content showed a signficant increase. The stimulating action of CCC on thegrowth of guayle plants is discussed in terms of increased plant N accumulation.

P. argentatum is used to treat allergic contact dermatitis. Guayulins A and B, and argentatines A-D, were isolated from dried aerial parts of *P. argentatum.* Argentatine a exhibited activity against *Candida albicans, Torulopsis glabrata, Hansenulla* (Hansenula) sp., *Klebsiella pneumoniae,* and *Pseudomonas aeruginosa* **(Martinez et. al., 1995).**

According **Wild et. al., 1995,** the stem boring curculionid *Listronotus setosipenn* is widespread and damaging to its host *Parthenium hysterophorus* in Northern Argentina and Southern Brazil. In detailed host teting studies, it was shown to have a restricted host range and, despite some feeding and development on sunflower in tests, to be a safe biological control agent against *P. hysterophorus.* Field releases in Queensland took place from 1982 to 1986 and the curculionid has established over several thousand hectares at numerous sites. Spread is, however, slow and the effect on the plant still negligible.

According to **Jayanth et. al., 1995,** *Zygogramma bicolorata* was introduced for biological control trials against *Parthenium hysterophorus* in India. The insect entered diapause over an extended period of time between July and December in Bangalore. Diapausing adults burrowed insect the soil, and emerged in May-June with the start of the monsoon rains. Percentage diapause increased over time, peaking at 72% during November. Non-diapausing adults were capable of breeding, under laboratory conditions, during the winter. Some adults bred both before and after diapause, during 2 consecutive years. Soil moisture played an important role in providing the conditions for burrowing or emerging from the diapause chambers. The studies also showed that diapausing adults had to be exposed to the high summer temperatures for diapause termination. It was possible to break diapause by continuous exposure to 30, 35 and 40 ^{0}C for 22 days, 9 days and 10 h, resp., during February March, about 3 months after starting. It is concluded that this method can be used to initiate mass multiplicantion for carrying out releases early in the season.

Studies conducted by **Poonam et. al., 1996,** *Alternaria alternata* is reported as a pathogen of *Parthenium hysterophorus,* with an overall frequency of occurrence of 30.33%. Its pathogenicity was shown both in vitro and in vivo experiments. The pathogen was neither capable of causing any sbustantial damage to the host tissues nor was it virulent enough to kill the host. It was concluded, therefore, that it does not qualify as a potential biocontrol agent of the weed.

Studies conducted by **Mishra and Bhan, 1996,** six herbicides (Metolachlor @ 2.0 kg/ha, Oxadiazon @ 1.0 kg/ha, Alachlor @1.0 kg/ha, Pendimethalin @ 1.0kg/ha, Oxyluorfen @ 0.15 kg/ha and Bentazon (e) @

1.5 kg/ha were tested to study their effectiveness for the control of carrot grass and associated weeds in soyabeans (*Glycine max*). Bentazon @ 1.5 kg/ha applied at 25 days after sowing effectively controlled carrot grass, dayflower (*Commelina benghalensis*) and yellow nut sedge (*Cyperus iria*). The highest grain yield and net returns were obtained in the weed free treatment, followed by Bentazon 2 1.5 kg/ha. The presence of weeds caused a 50.2% reduction in the grain yield of soyabeans compared with the weedfree control. Grain yield was negatively correlated with weed dry matter (with an increase of 1 g weed dry matter/m^2, grain yield was reduced by 1.445 n 0.368 kg/ha.

P. hysterophorus and wheat seeds were germinated in 0.15, 1.51, 15.17, 30.30, 45.50 and75.00 mm orthophosphoric acid (OPA) at 25^0C, and daily germination was counted upto 18d. In *P. hysterophorus* and wheat, the respective OPA concentrations causing 50% loss in seed germination were 0.19 and 16.7 mm, and 50% loss of dehydrogenase (oxidorecductase) activity were 0.15 and 1.9 mm, resp. The concentrations of OPA completely suppressing germination of *P. hysterophorus* and wheat seeds were 15.1 and 75.0 mm, resp. OPA sprayed at 15-60 mm on a stand of *P. hysterophorus* at the pre flowering stage caused wilting, desiccation and death of treated plants in about 2-8 h depending on the concentrations of the chemical. There was 100% mortality at the highest concentration **(Pandey et. al., 1996).**

Experiments were conducted to assess the effects of 5-20% aqueous extracts of flowers, stems and leaves of *P. hysterophorus* on seed germination and and establishment in *Cassia tora*. Results indicated that all extracts significantly inhibited germination and establishment in *Cassia tora*

and the effect increased with extract concentration. The leaf extract had the greates effect; the 5% extract gave 58% germination and 30% establishment, while the 20% extract gave 45% germination and 10% establishment, compared to 85% and 70% respectively in an untreated control **(Acharya, S.S. and Rahman, A. 1997)**.

According to **Dhawan et. al., 1998** a total of 16 fungal species belonging to 10 genera were isolated from the spormoplane of *P. hysterophorus.* All the species were Deuteromycetes except *Pcnicillium notatum* (Ascomycetes) and *Rhizopus arrhizus* (Zygomycetes). *Alternaria alternata* occurred the most frequently (30.33%) and *Epicoccum* sp.the least (00.16%). All the fungal species isolated are weak pathogens, not host specific and do not cause any disease on the green standing crop of the weed, except *A. alternata* which causes a minor leaf spot disease. The possibility of utilising these fungi as biocontrol agents of *Parthenium* is discussed.

Studies conducted by **Pandey, 1998,** *Parthenium hysterophorus* flower residue was inhibitory at 0.50% (W/V) and lethal at above 0.75% to *Lomna paucicostata.* Leaf residue was inhibitory at 0.50% and lethal at and above 1.00%. Stem residue was inhibitory at 1.00% but non-lethal at 1.25%, and root residue was inhibitory at 1.25%. The lethal concentration caused the desiccation of fronds and roots became flaccid. At lower concentrations, symptoms appeared or disappeared depending on the residue type, concentration and duration of the treatment. The lethal concentration caused a massive loss of electrolytes and UV absorbing substances from the roots, and loss of chlorophyll a, b and total chlorophyll and carotenoids.

An endemic collar rot disease of *Parthenium hysterophorus,* produced by *Sclerotium rolfsii* (*Corticium rolfsii*), is described for the first time. Maximum seedling mortality was recorded as a result of treatment with sprays of mycolia + water and sclerotia + water, and incubation for 4-6 days at 100% RH. The optimum temperature required for maximum seedling mortality was 25-30^{0}C. A 12-h dew exposure followed by 6 days incubation at 100% RH resulted in 50-90% seedling mortality **(Awadhiya and Sharma, 1996).**

The regeneration of *Parthenium hysterophorus* is described from field studies conducted in Jind, Haryana, India, during 1994. Stumps left after cutting back the plant sprouted, producing a large number of shoots from latent crown buds. Flowers were produced on such within thirty days. It was concluded that the rapid regenerative ability of *P. hysterophorus* was responsible for the dominance of this weed and the failure of manual control methods **(Dhawan et. al., 1998).**

According to **Jayanth, 1995,** as manual, chemical and competitive displacement methods are not practicable for the control of *P. hysterophorus*, biological control trials were initiated by importation and releases of the chrysomelid beetle *Z. bicolorata*. The insect established readily after releases were initiated in 1984, and started building up damaging population levels from 1988. Since then it has spread over an area of >200000 km^{2} in and around Bangalore, causing large scale defoliation of *Parthenium* and encouraging the growth of vegetation formerly suppressed by this weed. But the insect was noticed to feed on sunflower in a few isolated fields in Karnataka, raising fears of a host shift. However, detailed

laboratory and field studies clearly indicated that *Z. bicolorata* is unlikely to become a pest of sunflower. The results of the studies carried out to date indicate that *Z. bicolorata* has the potential to bring about permanent reduction in the density of *P. hysterophorus* in Bangalore and surrounding areas. However, it may be desirable to import additional natural enemies such as the leaf mining moth *Bucculatrix parthenica* and the seed feeding weevil *Smicronyx lutulentus*. Similarly, importation of host specific plant pathogens such as *Puccinia abrupta* var. *parthenicola* may also contribute to the successful biological control of this noxious weed throughout India.

Recent studies examining the development of *Sclerotium rolfsii (Corticium rolfsii)* as a mycoherbicide for the control of the noxious weed *Parthenium hysterophorus,* which can cause serious dermatitis with long term exposure, are reviewed **(Pandey, et. al. 1998).**

The Co-operative research Centre for Tropical Pest Management (CTPM) seeks to develop and implement cost – effective, environmentally friendly methods of *Parthenium* control. The role of the CTPM in Coordinating, integrating and funding studies on *Parthenium* is discussed. The CTPM is involved in collaborative research and technology exchange, including the determination and implementation of ways to transfer the knowledge generated into the agricultural community. Studies include the characterisation of ecotypes using DNA fingerprinting techniques and investigating the role of allelopathy, seed dormancy, seed banks and phenological attributes in the persistence mechanicsm (s) of *Parthenium.* Process based simulation models are used to monitor and predict future spread. Biological control studies involving phytophagous insects and plant pathogens are discussed **(Adkins et. al., 1998).**

A field experiment was conducted at Rajendranagar, Andhra Pradesh, during June 1988 to elucidate the relative allelopathic eficacy of plant extracts, namely from *Celosia argentea, Tephrosia purpurea, Flaveria australasica, Cassia sericea, Parthenium hysterophorus* and *Helianthus annuus* (sunflowers), on the growth and control of *P. hysterophorus.* Aqueous, cold and hot methanolic extracts of the plant species were obtained (1:10 w/v ratio) and sprayed at 4% dilution on three day old plants of *P. hysterophorus.* The observations recorded on plants height, root length, number of leaves and branches plant-1 of *P. hysterophorus* indicated better performance of extracts of *Cassia sericea* at 30, 60 and 90 DAS (days after sowing) compared to the other plant extracts under test. Among the extract types, methanolic extracts resulted in significantly lower density of *P. hysteroporus* than aqueous extracts. Extracts of *Cassia sericea* also resulted in lower seed production in *P. hysterophorus* plants **(Baby et. al., 1998).**

Problems including reduction in the recreational parks and associated areas, and the detrimental effects on human and animal health that result from *Parthenium* invasion of commercial crops, pastures and waste lands in rural and urban settings extension strategies illustrates the changing philosophy and modern methods used in extension programmes. General weed extension strategies, and specifically *Parthenium* weed control, are reviewed to explain why certain control methodologies are not adopted. Specific examples of the use of mass media and group approaches to *Parthenium* control in Queensland are examined **(Chamala et. al., 1998).**

According to **Dhawan et. al., 1998,** the seeds of vegetable species were placed in petri-plates with *Parthenium* seeds and their effects on *P. hysterophorus* germination were recorded. *P. hysterophorus* germination

was inhibited by the leachates of *Lycopersicon esculentum* (tomatoes) (7.10%), *Capsicum annum* (chillies) (26.06%), *Brassica compestris* var. sarson (40.28%), *Abelmoschus esculentus* (aubergines) (52.13%). *Solanum melongena* (okra) leachates did not inhibit *P. hysterophorus* germination. *P. hysterophorus* seeds stimulated the seed germination of okras (0.81%), chillies (33.66%), *aubergines* (15.19%) and *B. campestris* var. sarson (11.66%). Germination of tomato seeds was inhibited by 5.14%.

A field experiment was conducted in the wetlands of Coimbatore, India, on 2 rice crops grown in sequence during the dry and wet seasons of 1996-97. The main weed species present were *Echinochloa crusgalli, Leptochloa chinensis, Cyperus difformis, Marsilea quadrifolia* and *Monochoria vaginalis.* Puddling with a tractor-drawn cage wheel restricted weed growth and resulted in higher grain yield of 5.23 and 4.80 t/ha in the dry and wet seasons, respectively, compared to conventional puddling with a bullock drawn iron plugh (4.97 and 4.65 t/ha). This increase in grain yield resulted in a higher benefit : cost (B:C) ratio, especially in the dry season (2.42%). The traditional method of manual weeding twice (MW) controlled weeds effectively, but was not cost effective. Although allelopathic weed suppression was expected from the planting of *Parthenium* (*Parthenium hysterophorus*), the weed biomass was greater than in the other weed control methods. However, the grain yield was higher when *Parthenium* was sown in both seasons : 5.77 and 5.33 t/ha for dry and wet seasons, respectivey, compared to 5.53 and 5.12 t/ha with MW and 5.43 and 5.19 t/ha with butachor at 1.25 kg/ha + MW, in the respective seasons. The increase in grain yield with *Parthenium* made it possible to achieve better B : C ratios

of 2.59 and 2.40 in the dry and wet seasons, respectively (**Kandasamy and Raja, 1998**).

In a study done by **Kandasamy and Sankaran, 1999,** two field experiments were conducted at Coimbatore in India, between 1994 and 1995. The competitive abilities of major field crops (cereals, millets, oilseeds and pulses) grown under rainfed conditions and naturally occurring plant species against *Parthenium (Parthenium hysterophorus)* were evaluated. The recorded density and dry matter of*Parthenium* indicated that field crops which formed canopies early (Maize, Sorghum and Sunflower) effectively suppressed the population and biomass of *Parthenium.* In these crops branching, growth and flower head production of *Parthenium* was greatly reduced. Among the naturally growing plants in the surrounding area, *Abutilon indicum* and *Cassia sericea* reduced the *Parthenium* population to 52.0 and 59.3% of the control, respectively.

The effect of the fast growing introduced tree species *Eucalyptus tereticornis, Poplus deltoides* and *Leucaena leucocephala* on understorey vegetation in India was investigated. A nearby area of open ground without tree planting was used as a control. The distributionn, density, species diversity index and growth of *P. hysterophorus* was found to be poor in the plantations. The allelochemicals extracted from the soil surrounding the trees had similar effects on *P. hysterophorus* in vitro. The greatest effects were observed under *E. tereticornis,* followed by *L. leucoce* and *P. deltoides.* these results suggest that allelochemicals extracted from these tree species have potenial use in the control of *P. hysterophorus* (**Kohli et. al. 1998**).

According to **Dhileepan and McFadyen, 1998** biological control of *Parthenium hysterophorus* was initiated in 1977. At least 6 insect species and a fungal rust pathogen have been introduced and established in the field. The status of 2 other insects is still to be ascertained. The leaf-feeding beetle *Zygogramma bicolorata*, a stem-galling moth *Epiblema strenuana*, stem - boring weevil *Listronotus setosipennis* and seed -feeding weevil *Smicronyx lutulentus* are the main established biological control agents. Impact assessments in glasshouses, simulated field cages and open field trails have confirmed that *Z. bicolrata* and *E. strenuana* significantly suppress *Parthenium*. Agents with slow dispersal ability, including*L. setosipennis*, *S. lutulentus*, and *Puccinia abrupta* var . *partheniicola*, are being distributed to new areas through the Department of Natural Resources and local Landcare groups. Releases of the stem-boring moth *Platphalonidia mystica* were made over 5 years, but establishment has not been confirmed. Large-scale field releases of the stem-galling weeving *Conotrachlus* Sp. are continuing A new root-feeding weeving. The *Cesternus hirsutus*, and a new root-boring moth, *Carmenta ithacae*, have been imported from Maxica for host -specificity testing .It approved, these agents will be released into the field.

Studies conducted by **Evans, 1998,** fungal pathogens collected during surveys in the nectropics for coevolved natural enemies of*P. hysterophorus* are described and their biological control potential is assessed. Pathogens judged to have considerable potential as classical biological control agents within an integrated pest management strategy are discussed in detail, with particular reference to their pathogenicity and host specificity. The rust fungi *Puccinia abrupta* var. partheniicola and *P. melampodii* and the white smut, *Entyloma compositarum*, are considered.

According to **Hiremath and Ahn 1998,** a methanol extract of *Parthenium* was obatained by rotary vacuum evaporation at 40^0C. The extract was tested against a pest of rice, the paddy brown plant hopper *(Nilaparvata lugens)* in 1994 at Suwon, South Korea. During tests, 59.1% mortality of adult female hoppers was achieved. *Parthenium* extract was superior to other insecticidal plants tested, including *Acorus calamus* (30.1%), *Agava americana* (27.2%), *Bougainvilles spectabilis* (50.9%), *Calotropis gigantea* (30.0%), *Cannabis sativa* (50.0%), *Datura metel* var. alba (30.0%), *Eupatorium triplinerve* (41.7%), *Lentana camara* var. *aculeata* (31.1%), *Madhuca indica* (*M. longifolia*) (27.8%), *Ocimum americanum* (47.6%) and *Pongamia pinnata* (39.1%). The methanol extract yield of *Parthenium* was 19.4% The chloroform fraction was more toxic than the methanol extract. It is concluded that the utilization of*Parthenium* to produce biological pesticides would comlement the Indian *Parthenium* management strategy.

According to **Jayanth et. al., 1998,** biological control trials were initiated by the Indian Institute of Horticultural Research, using the leaf feeding beetle *Z. bicolorata* imported from Mexico. After field releases began in 1984, *Z. bicolorata* has readily established in Bangalore. Damaging population levels have been building up since 1988*Z. bicolorata* has spread over more than 200000 km^2 in and around Bangalore, causing large scale defoliation of *P. hysterophorus* the growth of vegetation formerly suppressed by this weed. However, *Z. bicolorata* was observed feeding on sunflowers in isolated field in Karnataka, suggesting a possible host shift. Detailed laboratory and field studies clearly indicated that *Z. bicolorata* is unlikely to become a pest of sunflowers and has the potential to permanently

reduce *P. hysterophorus* density in parts of India experiencing moderate weather condition. Importation and colonization of additional natural enemies, such as the leaf mining moth *Bucculatrix parthenica*, the seed feeding weevil *Smicronyx lutulentus* and the fungal pathogen *Puccinia abrupta* var. *partheniicola*, may complement *Z. bicolorata* for *P. hysterophorus* control throughout India.

Studies conducted by **Kauraw et. al. 1998,** *F. pallidoroseum* was isolated from seeds and infected leaves of its new host *P. hysterophorus*, collected from Jabalpur in India. Fungal growth on PDA (potato dextrose agar) and PDB (potato dextrose broth) at 26 ^{0}C was pale peach to brown, with white aerial mycelium. Spraying *F. pallidoroseum* at 100, 150 and 200g/litre of water onto *P. hysterophorus* reduced seed germination, seedling growth and plant height by 35%, branching by 29% and flower number by 38%. Soil inoculation, spraying and seed treatment reduced *P. hysterophorus* seed germination and growth. *F. pallidoroseum* is host specific and is thought to have the potential to be a potent and safe biological control agent.

Study conducted by **Kohli et. al. 1998,** showed that oils from *Eucalyptus globulus* and *E. citriodora* had a deleterious effectt on the noxious weed *Parthenium hysterophorus.* The germination of the weed was inhibited and the chlorophyll content and celluar respiration of the mature plants exposed to Eucalyptus oils were reduced significantly. This was accompanied by increased water loss resulting in complete wilting of the plants after 15 days of exposure to volatile oils. The oil from *E. citriodora* was more effective in causing injury to the weed compared to *E. globulus* oil.

The mulberry (*Morus* Sp.) leaf diet of mulberry and eri (*Samia cynthia ricini*) silkworms was supplemented with 1, 10, 15 and 20% solutions of *Parthenum hysterophorus* leaf extracts. The extracts were supplied once a day to silkworms, from the third instar until spinning. The leaf extract stimulated silkworms to feed and increased leaf utilization efficiency. The supplements resulted in healthy and vigorous larvae growth, ultimately producing bigger cocoons and improving all economic traits. The 20% solution was most effective and improved all economic traits as compared to the water control **(Patil et. al. 1998).**

According to **Mahadevappa, 1999** *Parthenium hysterophorus* is a native of north-east Mexico that has been accidentally introduced into numerous countries including India, Australia, USA, Brazil, China, Taiwan and parts of Africa. This major weed of arable and non-arable lands is reviewed. Being photoperiod and thermoperiod insensitive, P.*hysterophorus* flowers throughout the year, but rainy seasons are most conductive for growth and development. *P. hysterophorus* is a drought resistant plant and can grow in almost all soil types, but is particularly successful on vertisols. Evidence that *P. hysterophorus* causes bronchitis, acute detmatitis and eczema in man, and several cattle disorders, is discussed.*P. hysterophorus* also reduces the productivity of agricultural crops. A survey which identified 12 species, including *Cassia sericea* and *C. tora,* which effectively suppress *P. hysterophorus,* is reviewed. Mechanical, chemical and biological methods for *P. hysterophorus* control are discussed. The adoption of any single method has not previously been fully effective and it is concluded that integrated weed management is necessary for *P. hysterophorus* control.

The rust *Puccinia melampodii*, a potential biological control agent for *Parthenium hysterophorus*, is used as an example to describe the safety evaluation procedure for species introduction into Australia. Plants used in initial host range tests were selected to include those most likely to be infected (closely related species and literature reported hosts) and those of environmental and economical importance. Plant species which developed rust symptoms were retested. Different growth regimes and inoculation methods were used, including the use of a wind tunnel to simulate a more natural inoculum load, in order to determine the likelihood of infection occuring in the field. Cross inoculation studies were carried out using strians from different host species of *P. melampodii* to establish the existence of form specialies. The results of these studies are presented and the implications for the biological control of *Parthenium hysterophorus* are discussed (**Seier et. al. 1998).**

Studies conducted by **Singhal et. al., 1998,** the weed status of *Parthenium hysterophorus* in India including its threat to agriculture, and human and animal health are summarized. Current *P. hysterophorus* management techniques including mechanical weeding, pasture management, growing *P. hysterophorus* -suppressing plants, and chemical and biological control are outlined, and measures to prevent its spread are listed. Although *P. hysterophorus* extracts have been shown to have inhibitory effects on mulberry developments and growth, mortality of silkworm (*Bombyx mori*) larvae fed mulberry leaves supplemented with a 20% extract of *P. hysterophorus* was reduced to 18%; and the rate of successful rearing was increased from 5% to 82%. Cocoon weight and silk yield also increased.

According to **Singh, S.P., 1999,** the use of *Cassia uniflora* as a competitive displacement plant agianst *Parthenium hysterophorus* (Carrot weed) on unused land in Karnataka in India, is discussed. Three exotic insects were introduced into India as potential biological control agents. *Smicronyx lutulentus*, a flower feeding curculionid, could not reproduce in quarantine. *Epiblema strenuana*, a stem galling moth, was destroyed in quuarantine because it fed on the oilseed crop niger (*Guizotia abyssinica*). *Zygogramma bicolorata*, a leaf feeding chrysomelid, was brought out of quarantine in 1984 and released into the field. *Z. bicolorata* became established and spread to large areas covering Karnataka, Tamil Nadu, Andhra Padesh, Maharashtra and Kerala. After larvae completely defoliated *P. hysterophorus* adjoining sunflower plots, emerging adults migrated to sunflower border rows and showed exploratory feeding behaviour for a few days before migrating. *P. hysterophorus* pollen deposited on sunflowers and the hatching larvae failed to feed or develop. Feeding on sunflower s fed to the degeneration of flight muscles and ovarioles. *Z. bicolorata* recognized host *P. hysterohorus* much faster than non-host sunflowers and showed a preference for *P. hysterophorus* in choice experiments.

CHAPTER – III

METHODS

AND

MATERIALS

METHODS AND MATERIALS

The proposed work entitled "**An investigation on the effect of environment complex on *Parthenium hysterophorus* L. its adaptive strategies and management through non-chemical practices**" was carried out in the Department of Plant Pathology and Nematology, Allahabad Agricultural Institute, Allahabad. The details of the materials and methods employed in the experiment are given below:

(A) PHENOLOGICAL AND SEED STUDY

(i) Phenology

To note down the phenological events in the life of the plants, regular field visits were made and several plants were marked and observed twice in the month (first and third week) throughout the years 1999 and 2000.

(ii) Seed morphology

Seeds for the present studies were collected from different plants, cleaned and stored in the polythene containers. Weight of 100 seeds was taken in each case on an electronic balance, in triplicate. The shape and colour of the seeds as seen with the naked eye were noted.

(iii) Seed viability

Viability of seeds was tested by the tetrazolium methods of Porter et.al. (1947). Decoated seeds were kept in 0.5% solution of 2,3,5 triphenyl tetrazolium chloride (TTC) for 2h in the dark. If the embryo turned pinkish red, they were classed as viable.

(iv) Seed germination

Seed germination studies were performed in sterilized petridishes lined with a single layer of filter paper, moistened with distilled water. For continuous light, the petridishes were placed in white light obtained from six flourescent tubes of 40 watts each fitted at a distance of one metre from the platform (1000 lux) at $28 \pm 2^{0}C$. For dark, the petridishes were placed in a dark chamber. The criterion for germination was visual detection of radicle protrusion. The experiments were triplicated, each set being in triplicate and each petridish contained 10 seeds. The observations were recorded daily for a period of 7 to 10 days. To see the germination percentage in nature seeds were sown in an earthen pots during first week of January and August at 2 cm depth. The experiments were replicated and each set being in triplicate and each pot contained 10 seeds.

(v) Germination Velocity Index (GVI)

Germination velocity index was calculated for the seed sown in earthen pots during various seasons viz. rainy, winter and summer, by daily counts divided by number of days of germination (Babeley et. al. 1986)

(B) ECO-PHYSIOLOGICAL STUDIES

(I) Leaf morphology

Leaf area was measured by plotting the leaf margins on graph paper.

(II) Water relations

a. Plant water content

For the determination of plant water content (PWC) plant samples (leaves) were quickly brought to the laboratory and weighed immediately

with the help of an electric balance. Then the material was dried at 80^0C in an oven and reweighed after 24 h and PWC was determined as follows:

$$PWC = \frac{\text{Fresh wt} - \text{Dry wt.}}{\text{Dry wt.}} \times 100$$

b. Relative water content

For the determination of relative water content (RWC) freshly detached leaves were quickly weighed and kept on moist cotton pad covered with wet filter paper for maximum turgidity and their turgid weight was taken after 6h. The material was then dried at 80^0C and reweighed after 24 h. The RWC was calculated as follows, according to Weatherey (1950).

$$RWC = \frac{\text{Fresh wt.} - \text{Dry wt.}}{\text{Saturated wt.} - \text{dry wt.}}$$

c. Water deficit

Water deficit (WD) of plant was calculated according to Stocker (1929).

$$WD = \frac{\text{Saturated wt.} - \text{Fresh wt.}}{\text{Saturated wt.} - \text{Dry wt.}} \times 100$$

d. Bound water

Tissue bound water (BW) of plant was determined by measuring the fresh wt., air dry wt. and oven dry weight. Calculations were done by the following formula given by Schonbeck & Norton (1929).

$$BW = \frac{\text{Air dry wt.} - \text{Oven dry wt.}}{\text{Saturated wt.} - \text{Oven dry wt.}} \times 100$$

e. Hygroscopic capacity (HC)

It was calculated by the following formula –

$$HC = \frac{\text{Air dry wt.} - \text{Oven dry wt.}}{\text{Oven dry wt.}} \times 100$$

f. Osmotic potential

Osmotic potential of leaves was determined, according to Janardan et. al. (1975). For this 1 g. of fresh leaves was ground to paste, strained hrough a muslin cloth and made the final volume upto 25ml by adding distilled water.

The electrical conductivity (EC) of cell sap was measured with the help of digital conductivity meter. The OP (-bars) of the cell sap was calculated as follows :

$$OP = \frac{EC \times 0.36 \times d.f.}{0.987}$$

where, EC = electrical conductivity in millimhos/cm. of plant extract at 25^0C

d.f. = dilution factor

0.987 = factor converting atmospheric pressure.

$$d.f. = \frac{25 \text{ ml} \times \text{fresh wt (1g)}}{\text{moisture content in 1 g.}}$$

III. Stomatal studies

The observations on stomatal features were made with isolated epidermal peelings from both the surfaces of fully mature leaves. The measurements of number of stomata per unit area and the stomatal size were made with a microscope fitted with a precalbrated ocular micrometer.

Density of hairs was also measured by the same method and the observations were taken from the six different peelings and the standard deviation was calculated for each case. The stomatal index (SI) was determined according to the following formula.

$SI = S (S +E)^{-1} X 100$

where S is the number of stomata per (m^2)and E is the number of epidermal cells per m^2.

IV. Water loss

Water loss from freshly cut twigs was measured over a period of 30 minutes by rapid weighing method three times a day. This is supposed to be the most satisfactory method for comparative study of water loss (Hellmuth, 1968). For the present study the water loss was estimated in percentage. The water loss was measured 10, 20 and 30 minutes after the detachment. To reduce variability, twigs were taken from the same group of plant in a particular habitat.

C. BIOCHEMICAL ANALYSIS

For the present study leaves of the *P. hysterophorus* were examined for sugar, chlorophyll, protein, nitrogen and pigment estimation. For sugar and chlorophyll, fresh leaves were used, while dry leaves were used for protein analysis. Sugars were estimated using Anthrone reagent (Plummer, 1971), protein by micro-kjeldahl method (Peach & Tracey, 1955), and cholorophyll by Arnon (1949) method.

For estimation of proteins, the leaf samples were digested and analysed for total nitrogen with microkjeldahl method and then the values so obtained were multiplied by 6.25 to get the total crude protein content.

(D) MANAGEMENT STRATEGY

Although several methods have been developed for the control of this weed, each has its own disadvantages and limitations. Therefore, under the present study all the possible and available measures, to control the weed, were tried under field conditions to evolve an integrated management strategy to control the weed.

(I) Manual and Mechanical method

Under this method, plants (*Parthenium hysterophorus*) wherever seen were uprooted and destroyed. Plants were uprooted at the stage of flowering to prevent seed formation and dispersal.

(II) Isolation & culturing of fungus as a bio-control agent

Fusarium oxysporum was isolated from pigeon pea plant affected with wilt disease. The fungus was identified and then cultivated on potato dextrose medium (PDA). About 10 days old culture (100, 150 and 200 g/l of water) was used for the inoculation of seeds. The prepared solution was sprayed on about 2 months old plants. The experiment was carried out with three replications with respective control observations were recorded on germination and mortality of plants sprayed.

(III) Effect of different amount of inoculum of *F. oxysporum* at different growth stages of *Parthenium hysterophorus.*

The experiment was carried out in the years 1999 to 2001. Three doses of inoculum (spore + mycelium of *F. oxysporum* 100, 150 & 200 g/l of water were sprayed at different growth stages of *Parthenium* namely vegetative stage, before and after flowering. Observations were recorded on plant height, number of branches and number of flowers per plant. The treatments were replicated thrice in a RBD.

(IV) Effect of *F. oxysporum* on seed germination and seedling mortality of *Parthenium hysterophorus* in petriplates

Twenty five *Parthenium* seeds were shown in each petriplate containing two moist filter papers and the seeds in plates were sprayed with *F. oxysporum* spore suspension. Four replicates were maintained. The plates were in- cubated at 25 ± 1^{0}C for 15 days. Water spray was used as control.

The observation on percentage seed germination andseedling mortality was recorded.

(V) Methods of application :-

The experiment was conducted in the years 1999 to 2001. *F. oxysporum* was grown on potato dextrose medium. Ten days old culture (100 g/l of water) was used for inoculation by three methods viz seed infestation, soil infestation and spray on seeds. The experiment was carried out in each month for knowing the best month and best method of application of the fungus for the control of *Parthenium*. The sowing of the seeds was done

from July to June in each year with three replications with respective controls. Observations were recorded on germination of seed and seedling mortality after one month of sowing.

(VI) Effect of Competitive plants (BAs) on*Parthenium hysterophorus.*

Field investigations were carried out in the years 1999 to 2001 to study the effect of certain identified competitive plants of the surrounding and their population variation on the growth of *Parthenium.* Viable seeds of all the competitive plants were sown in the field where *Parthenium* plants had natural seedlings. Treatments were replicated thrice in RBD with a plot size of 5m x 4m. The population of competitive plants and growth of *Parthenium* were estimated at 75 days of sowing of seeds.

(VII) Effect of herbicides on*Parthenium hysterophorus.*

2, 4-D sodium salt and round up (41%ai) at three different doses viz. 1 kg/ha, 1.5 kg/ha and 2.0 kg/ha were applied to the full grown plants of *Parhenium hysterophorus.* The experiment was carried out with three replications with respective control, observations were recorded on chlorophyll disintegration (after 4-5 days of spraying) and mortality (after 10 days of spraying) of plants sprayed.

VIII Preparation of Extracts from the Competitive plants (BAs).

Roots of the BAs viz. *Cassia uniflora, Abutilon indicum* and *Tagetes erecta* were collected, washed thoroughly with running water and final washing was done with 90% alcohol in order to suppress the microbial activities. After washing 100gm of ground roots of the said plant were grinded

separately with 100 ml of distilled water, to prepare the extract of the said test plants.

Germination test and Seed vigour.

The extracts so obtained were diluted into different concentration of 100, 75 and 25 percent. Uniform, healthy and viable seeds of *P. hysterophorus* were collected. Germination tests in petridishes were performed under laboratory conditions using the above concentrations.

Seed vigour was calculated as shown below:

$$\text{Seed vigour} = \frac{\text{Summation of quotients of daily counts.}}{\text{Number of days of germination.}}$$

CHAPTER – IV

RESULTS

AND

DISCUSSION

RESULTS & DISCUSSION

4.1 PHENOLOGICAL AND SEED STUDIES

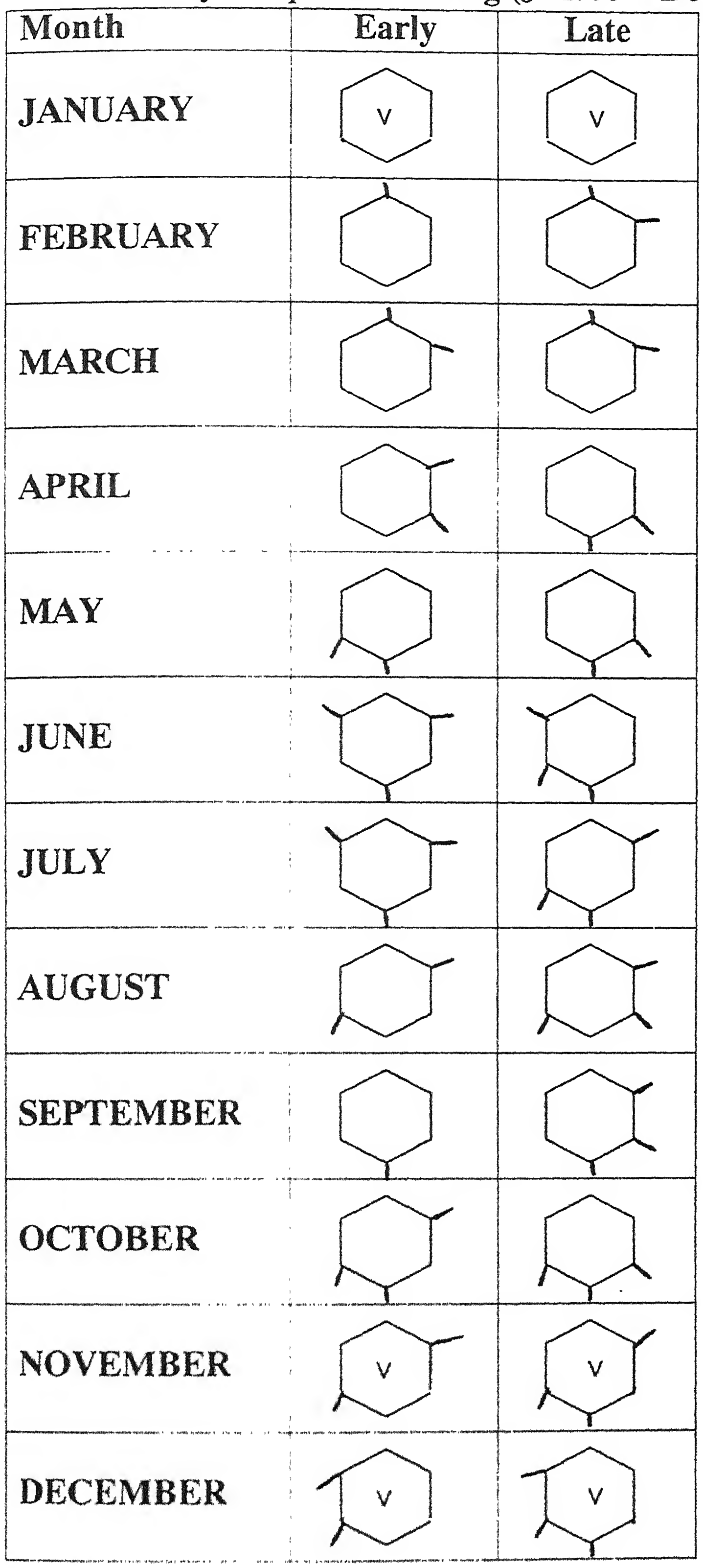
To study the various phenomena like leafing, flowering, fruiting, etc. regular observations were made twice, in the first and third week of the month throughout the years 1999-2000 and 2000-2001. A particular plant species is supposed to behave and perform all the above natural functions in a very scheduled and regular way, but it is not so if we go to field and observe the plant behaviour regularly. One can find very interesting and diverse behaviour. Plants may behave in a scheduled manner where climatic conditions are uniform and normal but in contrast where plants are exposed to erratic rainfall, extreme and variable temperature, an extraordinary behaviour is very natural. Phenological study is such an important study that even the International Biological Programme provided a strong impetus to the studies of phenology in the United States and led to the first modern summary of this field in the english language.

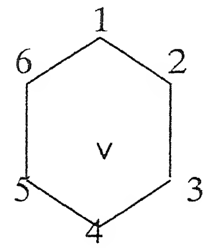
A number of studies pertaining to management of *Parthenium* plant have been done but nothing substantial has been done on this aspect of the plant. The present study, therefore, is the primary step and is restricted to only field observations, which led to discover the diversities in such phenomenon.

4.1.1: Phenological Account

Observations, regarding phenology of *P. hysterophorus*, are presented here in the form of phenograms (fig. 4.1 & 4.2) during two years consequently (1999 & 2000). The various stages of phenograms represent: vegetative

Fig 4.1: Phenological observations in the form of phenograms of *P. hysterophorus* during (Jan. 99 – Dec. 99).





Benzene ring depicting all the seven growth stages of *Parthenium hysterophorus*.

1. Vegetative growth
2. Flowering
3. Fruit setting
4. Fruit/seed maturation
5. Seed dispersal
6. Leaf shedding
7. Vegetative state/dormant.

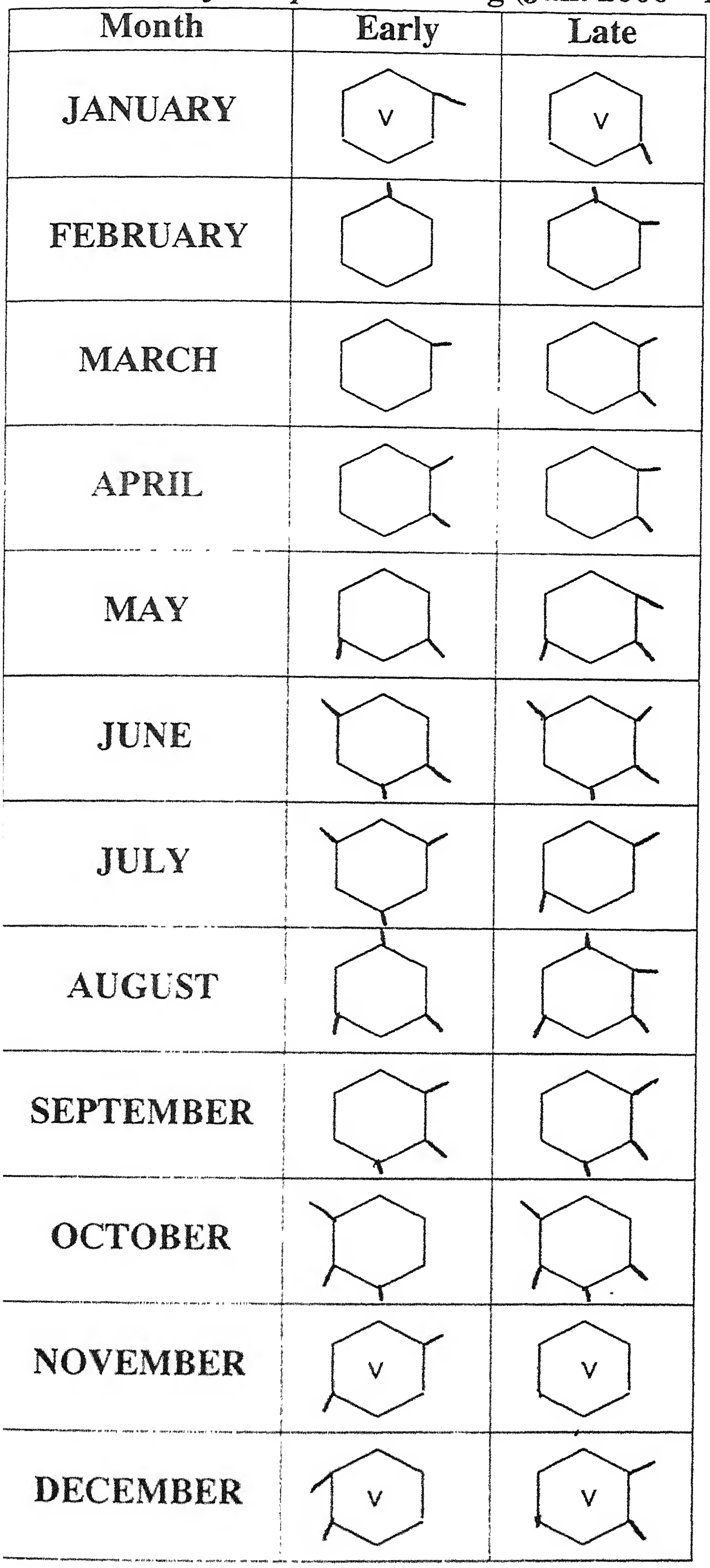
growth (1); flowering (2); fruit setting (3); fruit/seed maturation (4); seed dispersal (5): leaf shedding (6); and vegetative state/dormant (7).

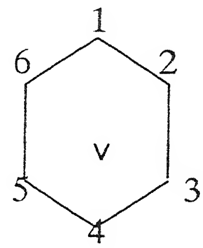
One of the interesting and exciting feature of this plant species is that its availability in the field can be observed throughout the year. Two distinct populations make it a complex weed. The auxiliary population is day neutral and flowers round the year, while the terminal population is long day and flowers during summer months only. The plants are non-latiferous and non-aromatic showing juvenile and adult phase. The adult phase is erect, much branched, upto 2m or more in height, stem whitish hairy, octangular and longitudinally grooved whereas the juvenile phase is rosette with darkgreen, pinnectisect radicle, large sized leaves which are spread on the ground forming mats and not allowing any vegetation underneath. The plant can complete even three to four generations in a year.

It germinates mainly in the month of Feb – March and attains peak growth in June-July and produces seeds in Sept.-Oct; completing its life cycle in 200-240 days Vigrous densities and vegetative growth in this plant species were recorded during rainy season.

Flowering in this species was observed almost in all month. Rosette formation/vegetative state was seen during winter season i.e. November to January. Rosette formation in the plant for same period was to tide over the diverse condition. Leaf shedding normally took place in the months of May & June when there was extreme temperature in the region. Seed maturation took place usually in the month of June, July and August and thereafter usually seed dispersal begins.

Fig 4.2: Phenological observations in the form of phenograms of *P. hysterophorus* during (Jan. 2000 – Dec. 2000).





Benzene ring depicting all the seven growth stages of *Parthenium hysterophorus*.

8. Vegetative growth
9. Flowering
10. Fruit setting
11. Fruit/seed maturation
12. Seed dispersal
13. Leaf shedding
14. Vegetative state/dormant.

The study of organisms in relation to climate has been termed as phenology. The study of various stages of the life cycle of a plant starting from seed or perennating rootstock till it dies gives interesting history to understand its biology. Plant included in this category completes 3 – 4 generations in a year and it flowers, fruits and seed in each life cycle, but this does not mean that they have a very fixed pattern and time for all these events to happen regularly as flowering in this species has been observed almost throughout the year. The plant remained dormant in the form of rosette formation for some period to tide over diverse condition. Leaf shedding normally takes place in the month of May-June when there is extreme temperature in the region.

Turner & Randall (1987) have tried to relate various phenophase with the various climatic factors; and according to them:

(1) A positive correlation with temperature means that higher temperature retards an event; viz flowering, fruiting, leafing, etc. Although in the present study low temperatures during Dec-Jan were found to make the plant in dormant/rosette form.

(2) An inverse correlation with rainfall means that higher rainfall accelerates an event.

(3) Inverse relationship with both temperature and rainfall imply that higher temperature and more rainfall both accelerates an event.

(4) Positive relationships with both temperature and rainfall imply that higher temperature and more rainfall both retard an event.

(5) An inverse correlation with temperature and a positive correlation with rainfall imply that higher temperatures accelerate and higher rainfall retards an event.

(6) An inverse correlation with rainfall and a positive correlation with temperature imply that higher temperature retards and higher rainfall accelerate an event.

4.1.2. Seed Morphological Studies:

The colour pattern, shape and weight (100 seeds in mg) of *Parthenium* seeds are presented in the table-(4.1). Inspite of economic importance of seeds little information exists on this aspect. Different types of plants have different colour and weight of seeds. Not only do these characteristics vary between species but to a large extent, variations particularly in weight and colour also exists with in the given species in the present study, as reported in the table-(4.1), variations in colour and weight in the seeds of *Parthenium* were observed with regard to shape no variation was reported but one distinguish feature of seed is that it has dorsiventrally flattened structure which is supposed to be helpful in easy dispersal of seeds of *Parthenium* to distant places.

A study of seed morphology has many applications. To introduce a suitable plant species in a particular habitat is quite difficult, without recognizing the seed, and its possible response towards a particular climate. Characteristics of seeds, more than any other character that the plant possesses, requires precise integration and coordination between different functions in order to have successful reproduction. Moreover, the adaptive values of seed size, shape, seed output, nature of the embryo, and the stored food associated with it may conflict with each other to such an extent with

Table 4.1: Colour, shape and weight (100 seeds in mg) of *Parthenium hysterophorus*.

Lot	Colour	Shape	Weight (100 seeds in mg)
1.	Dark grey	Cone shaped, shrivelled With dorsiventrally flattened structure	481.63 ± 4.3
2.	Brown		489.87 ± 4.6
3.	Light grey		516.64 ± 6.8

Table 4.2: Viability and germinability (in percentage) test in seeds of *Parthenium hysterophorus*.

Type	Viability	Germinability
A (Fresh seeds)	94.67 ± 3.86	76.62 ± 1.87
B (6-8 months old seed)	90.54 ± 2.93	85.36 ± 2.14

Table: 4.3: Total germination percentage (TGP) and germination velocity index (GVI) of *P. hysterophorus* during various seasons.

Season	Total Germination Percentage (TGP)	Germination Velocity Index (GVI)
Rainy	83.33 ± 6.3	3.65
Winter	71.68 ± 8.2	2.87
Summer	63.84 ± 11.67	1.96

reproductive efficiency in a particular habitat depends upon a compromise among those conflicting demands. The number and diversity of such compromises are responsible to a great degree for the diversity of angiosperms with respect to the characteristics that are ordinarily regarded as diagnostic for their major categories (Stebbins, 1971).

Seeds of two types viz. fresh seed and 6-8 months old seeds stored have been tested for their viability and germinability (in percentage). Results obtained have been presented in the table (4.2) from the data recorded in this table, it is clear that germinability of *Parthenium* seeds is more in 6-8 month old seeds of *Parthenium* as compared to that of fresh seed. With regard to viability higher value was recorded in fresh seeds and lesser in stored seeds.

The viability, dormancy and conditions required for germination of different seed populations set primary limits to the evidences of the species populations in different seasons and habitats. The very existence of variety of germination regulating mechanisms, and their frequent complexities are proofs that they are ecophysiological adaptions. These adaptions increase the potential for survival of the species, and have been formed in he natural pattern of evolution. Seed germination is an important determination for the population of a species to maintain itself in a particular habitat.

According to Baker (1974) most interesting feature of many weeds is their ability to set viable seeds quickly and in enormous quantities. Sen (1977 a) stated that the viability depends upon the kind of seeds, and low temperature and high carbon dioxide concentration favour the retention of viability for longer periods. The (1984) buried *Parthenium* seeds can remain viable much longer than previously thought. In the present study also the

stored seeds of *P. hysterophorus* indicate an increase number of germinable seeds (table-4.2). This has implications for future management of the weed, particularly in cultivated areas where seed burial occurs regularly.

Total germination percentage (TGP) and germination velocity index (GVI) of *P. hysterophorus* seeds were calculated and the observations are presented in the table (4.3).

The seeds of the test plant exhibited the maximum germination percentage of 83.33 during rainy season and minimum 63.84 percent in summer season and during winter season the germination percentage was 71.6. With regard to germination velocity index (GVI) as evident from the table (4.3) it was invariably higher during rainy season, lesser in winter and least in the summer.

Seed germination represents the cessation of dormancy and restoration of active embryo growth. A dry seed has a very low rate of metabolism; and is capable of metabolic reactions provided initial hydration of enzyme proteins occurs. The emergence of radicle through testa is the first visible sign of germination. Imbibition of water by seeds marks the beginning of germination leading to : (I) Lysis of reserve metabolites (II) respiration and (III) changes in cellular organelles. The initial metabolic changes during seed germination is the breakdown of reserve metabolites like proteins, carbohydrates, lipids, help of enzymes present already in the seed that are activated after hydration.

Functionally, seed is a device for reproduction, multiplication, preservation and perpetuation of a particular plant species so as to ensure its continuation and establishment. Thus, the seed germination is one of the

primary and basic step towards the understanding of the ecophysiology of plants. Germination in seed plants can be defined as the sequential series of morphogenetic events, which cause a quiescent seed, with a low water content to show a rise in its general metabolic activity and to initiate the transformation of an embryo into a seedling.

Germination velocity index (GVI) acts as a very important parameter to sort out the fastest germinating seed type in the same species. In *P. hysterophorus* seeds the maximum value of GVI was during rainy season followed by winter and then during summer.

Both seed size and the specific time of seed germination have a significant influence on the survival of individuals within a population. However, in some instances, when environmental hazards are not great, the timing of germination may play a less significant role in determining survival of the seedlings.

4.2: ECO-PHYSIOLOGICAL STUDIES.

4.2.1: Leaf Morphology.

Leaf size of *Parthenium hysterophorus* recorded during different developmental stages and seasons in the campus of the Allahabad Agricultural Institute (Deemed University) is presented in the table (4.4). It is observed from the data, recorded in the table that plant shows variation regarding leaf area during the various developmental stages and seasons. The first and second leaves from the apex show almost equal size in all the three seasons but there is a gradual increase from the third leaf onwards. The leaf showed higher value with regard to area in rainy season and lesser in winter season and least in summer season.

Table 4.4: Leaf area (sq mm) at various growth stages and seasons in *Parthenium hysterophorus*.

Leaf insertion level from apex	Area (mm^2) during various seasons		
	Rainy	Winter	Summer
1	96.87 ± 0.36	89.53 ± 0.33	65.21 ± 0.21
2	97.01 ± 0.35	90.73 ± 0.34	65.62 ± 0.23
3	113.84 ± 0.29	102.58 ± 0.25	74.58 ± 0.20
4	118.69 ± 0.27	107.28 ± 0.26	81.64 ± 0.35
5	124.82 ± 0.18	108.64 ± 0.31	87.67 ± 0.36

Jardeni (1938) observed a gradual reduction of leaf size in *Ononis leiosperma* in summer. Cunningham & Strain (1969) opined that rain induces the emergence of new crop of leaves, which expand, and their final structure depends on how much water is available for cell expansion. As soil moisture supplies are developed, the leaves developing on the branch have more area. Orshanky (1938) found in *Ononis natriz* that the summer leaves gradually reduced in size passing through a series of trifolicate-unifolicate petiolate condition so that only stipules of very much reduced size were preserved in the late summer thus resulting 85.% reduction of the transpiring organs.

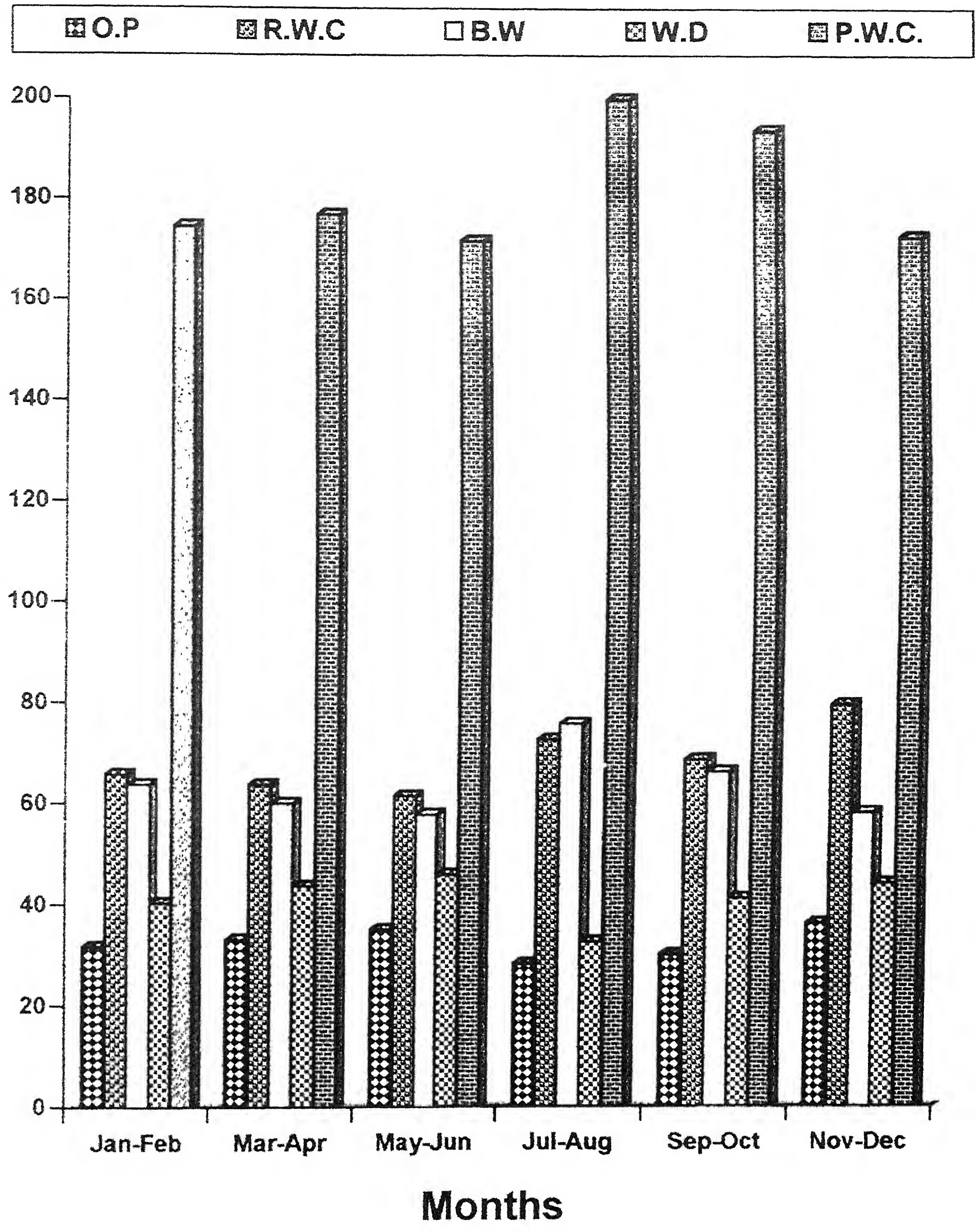
It. therefore can be concluded that water shortage during summer season, may cause a reduction in the total area of leaf which shows its adaptability under different water regimes as availability of less water supply couples the plants to reduce the leaf size, thus preventing the excessive water loss.

4.2.2: Water relation:

Percentage of osmotic potential (OP), relative water content (RWC) bound water content (BWC) water deficit (WD) and Plant water content (PWC) in the leaves of *Parthenium hysterophorus* were calculated and average during 1999/2000 & 2001values thus obtained are presented in the Fig.(4.3).

The percentage of osmotic potential in the test plant was maximum (-28.34 bars) in the month of July-August, which continued to decrease upto November-December (-38.43 bars). Then it slightly rose in January–

Fig. 4.3: Average percentage of Plant water content (PWC) Relative water content (RWC) Bound water content (BW) Water deficit (WD), and Osmotic potential (OP) in *Parthenium hysterophorus* during the years 1999-2001.



February (-31.67 bars) and again a gradual decrease was observed in the following months till May-June (-35.87 bars), which was the lowest.

With regard to relative water content the plant showed the highest value in the month of July-August (72.67%) and the lowest in May-June (61.48%.)

As far as percentage of bound water is concerned, maximum value was obtained in the month of July-August (75.86) and minimum value was observed in the month of May-June (57.81).

Regarding water deficit of the plant it was 40.32% in the month of January-February which increased gradually and the maximum value was recorded in the month of May-June (45.89%) fell sharply in July-August and reached to its minimum (32.68%) and then again a rise was observed in the following months. In case of plant water content in the said plant as recorded in the figure (4.3) the highest value was observed in the month of July-August (199.85%) then it declined gradually up to November - December (172.53) and a rise was observed in January-February (174.44%). The lowest value was recorded in May-June (171.58%).

In land plants, the assimilating parts of which are in contact with air, continually lose their water by transpiration, so the establishment of suitable water relations is the first requirement (Larcher,1983). Water relations and stomatal behaviour are the important devices which reflect the ability of plants to economise essential requirements under the prevailing climatic and edaphic conditions (Jarvis, 1967, Sen et al, 1972).

It has been reported that water potentials were lowest during hot, dry summer and highest in cool and moist winter season in *Larrea divarciata* near desert, California. Sharma, 1976 reported high osmotic potential during rainy season and low during winter season in *Merrcmia aegyptia.*

In the present investigation highest osmotic potential was observed in July-August and lowest during November-December in the test plant. In the present study the osmotic potential value ranged from-28.34 to -36.43 bars. All these monthly fluctuations have been related with the soil moisture conditions as the highest values were obtained during the monsoon months of July-August. The percentage water content in this study varied from 171.58 to 199.85. Daiya (1981) while investigating water relations of *Cassia* species observed R.W.C values between –71 to 91%. Sharma (1976) recorded high LWC during rainy season and low during winter and summer seasons in *Marremia* species. Daiya (1981) observed high LWC in July and low in October in *Cassia obtusifolia.* Kumar (1984) recorded the highest LWC values in August. In the present investigation also the highest value regarding PWC was recorded during July-August for the test plant. From these observations it can be concluded that high LWC is related with more soil moisture content which is obtained during rainy season. In the present study, highest PWC value was observed in July-August and lowest in may-June in the test species, which is in agreement with the observations of Daiya (1981), Lekhak (1983) and Kumar (1984).

Lekhak (1983) observed high values of water deficit during summer and low during rainy season in many desert plants. In case of *B. articularis, P. crispa* and *H. marifolium* the lowest values of water deficit were recorded during July-August and highest in May-June (Kumar,1984). In the present study

also the highest value of WD was recorded during May-June(Summer season) and lowest in July-August (rainy season).

Bound water which is unfree or combined water was found to be higher in xeropytes than in mesophytes. Vedia et al. (1961) had correlated plant hardiness and especially drought hardiness the relative amount of bound water in tissues, the more the bound water, the harder/turgid the plant. In the present study also the highest B.W. value was recorded during July-August and lowest during May-June.

Shreve (1951) claims that physiological adaptations are not all matched by structural ones and so plant must be analysed physiologically and structurally through out its developmental cycle before the complex of its adaptations can be defined. The water relation study of the plant attributes to the understanding of adaptability and survival strategies of any species (Sen, 1973.).

4.2.3: Stomata:

Data on number of epidermal cells, stomatal density, stomatal size and stomatal indices on upper and lower leaf surfaces of the plant are presented in the table 4.5.

It is evident from the table 4.5 that the test plant showed highest stomatal densities for upper (112.35 ± 5.6) and for lower (136.5 ± 5.9) surfaces of leaves during June and May respectively. The lowest densities were observed during January (84.15 ± 2.28) and July (76.1 ± 3.2) for upper and lower surfaces respectively. The stomatal index was minimum (6.79) during January for upper and 4.43 in July for lower surfaces. The higher stomatal

sizes were observed during winter months and during rest of the months the stomatal sizes were not stable.

Because the stomata regulate the bulk of water loss from leaves, it might be expected that stomatal adaptations within species that affect both the quantity and patterns of water loss could be common. Such stomatal adaptations involved reductions in the number and / or size of stomata, alteration in leaf morphology so that stomata are recessed in to cryptsso as to increase diffusion resistance to vapour transfer and alterations in stomatal response to environment or inter water stress resulting in water conservation.

Plant responses to environment are frequently influenced by stomatal functioning, through effects on water use, the development of water deficit, net photo-synthesis and temperature regulation. In ecophysiology, predicting stomatal responses to environment and relating these responses to the functioning and physical state of plants are important objectives.

Turner (1979) has stated that the stomatal frequency is not unique for a particular species or cultivar, but varies with environmental conditions. Meidner & Mansfield (1968) have also expressed a similar view that the number of stomata per unit area varies not only between species but also within anyone species owing to the influence of environmental factors during growth.

In the present investigation, it has been found that the stomatal index and stomatal density varied much at different seasons in the plant species studied. Maximum stomatal density was recorded during summer. It was in confirmation with the findings of Rippel (1919), Salisbury (1927), Pen - found (1931-1932), Gindel (1968), Kumar (1981) and Lekhak (1983).

Table 4.5 Number of stomata and epidermal cells (sq. mm), stomatal size (l x b in μ) and index in *Parthenium hysterophorus* during the years 1999-2001.

Month	No. of epidermal cells		No. of stomata		Size of the stomata	Stomatal index	
	U	L	U	L		U	L
Jan	1155 ± 49.6	1054.5 ± 66.3	84.15 ± 2.28	82.35 ± 3.8	27.3 ± 2.4 x 23.6 ± 1.0	6.79	7.24
Feb	1105.5 ± 84.15	891.0 ± 52.45	97.15 ± 3.8	87.5 ± 15.1	30.4 ± 2.6 x 15.0 ± 2.3	8.08	8.94
Mar	1113.5 ± 42.8	877.5 ± 36.5	89.5 ± 4.45	80.35 ± 8.35	28.5 ± 2.6 x 14.7 ± 2.6	7.44	8.39
Apr	1267.0 ± 104.6	1206 ± 55.6	106.0 ± 6.6	98.8 ± 8.5	24.6 ± 2.8 x 21.8 ± 5.6	7.72	7.57
May	1309.0 ± 124.5	1773 ± 97.5	112.15 ± 5.75	136.5 ± 5.9	25.8 ± 2.3 x 21.4 ± 2.6	7.89	7.14
June	1252.5 ± 91.0	1802.5 ± 54.0	112.35 ± 5.6	135.3 ± 2.8	25.4 ± 2.6 x 21.3 ± 2.6	8.23	6.98
July	1305.0 ± 28.35	1639.0 ± 79.1	104.5 ± 4.4	76.1 ± 3.2	25.6 ± 2.7 x 21.1 ± 2.7	7.41	4.43
Aug	1262.0 ± 24.3	1667.0 ± 76.2	105.5 ± 8.53	81.35 ± 3.6	24.3 ± 2.6 x 21.8 ± 2.6	7.71	4.65
Sept	1289.0 ± 47.53	1609.0 ± 98.5	104.5 ± 4.25	77.15 ± 1.25	25.6 ± 2.8 x 21.4 ± 2.4	7.49	4.57
Oct	1065.5 ± 58.3	1481.5 ± 56.5	91.3 ± 6.45	85.35 ± 4.04	27.2 ± 2.2 x 22.4 ± 2.1	7.89	5.44
Nov	1266.5 ± 35.8	1597.5 ± 32.5	106.0 ± 2.0	80.15 ± 5.35	25.5 ± 2.6 x 21.1 ± 2.4	7.72	4.77
Dec	1218.0 ± 54.8	1436.0 ± 64.2	97.3 ± 5.65	78.1 ± 1.8	28.50 ± 2.6 x 14.9 ± 2.7	7.40	5.16

Habitat of a species plays an important role in distribution of stomata over two leaf surfaces. Some prejudice exists in general botanical texts as to the adaptive advantage of different stomatal distribution under various environmental conditions.

Wood (1934) in a study of sclerophyllous plants in South Australia, However, reported an opposite trend. Majority of arid zone plant species showed amphistomatic conditions with the pattern of stomatal density higher on lower surface (Lekhak;1983; Kumar. 1984). The adaptation of plants to arid environment is influenced by stomatal responses and a reduction in water loss by plant has been sought to conserve soil moisture to increase survival of plant under drought conditions (Turner & Waggoner, 1968).

The data on seasonal variations in the stomatal opening and number of hairs on two leaf surfaces of *P. hysterophorus* are given in the table (4.6) the trend of stomatal opening on both the upper and lower epidermis during the three season was observed as follows.

Rainy : Morning > Evening > Noon.

Winter : Morning > Noon > Evening.

Summer : Evening > Noon > Morning

The percentage stomatal opening was higher irrespective of day hours in the upper epidermis than that of lower epidermis in all the three seasons, except in the winter season in which it was in contrast. The values with regard to the number of hairs were also higher in the upper epidermis than those of lower epidermis. The maximum value regarding hairs was recorded during the summer season, minimum in winter season and least during the rainy season. Plants hairs have been linked either directly or indirectly to increased water use efficiency pubescence may effect transpiration directly through its influence on the water diffusion bounding layer of transpiring

Table 4.6 **Variations in percentage stomatal opening at three timings (morning, noon and evening) in *Parthenium hysterophorus* during various seasons in the years 1999-2001.**

Seasons	Timing	Stomatal opening (%)		No. of Hairs.	
		Upper	Lower	Upper	Lower
Rainy.	M	98.87±2.14	89.16±2.4	13.0±1.80	7.5±1.16
	N	76.58±2.86	68.58±3.0	4.0±0.90	6.0±1.10
	E	86.67±3.0	81.73±2.6	8.0±1.53	5.1±1.06
Winter.	M	85.56±3.1	89.95±2.60	14.5±1.97	12.5±1.64
	N	76.69±2.87	78.69±3.0	24.23±1.96	11.6±1.54
	E	70.32±2.14	75.18±2.98	15.6±1.53	9.8±1.01
Summer.	M	63.87±2.10	59.83±1.67	20.60±1.10	15.61±1.89
	N	68.51±1.87	63.87±1.81	19.10±1.16	9.50±1.61
	E	88.79±2.87	82.63±1.96	29.5±2.6	14.2±1.67

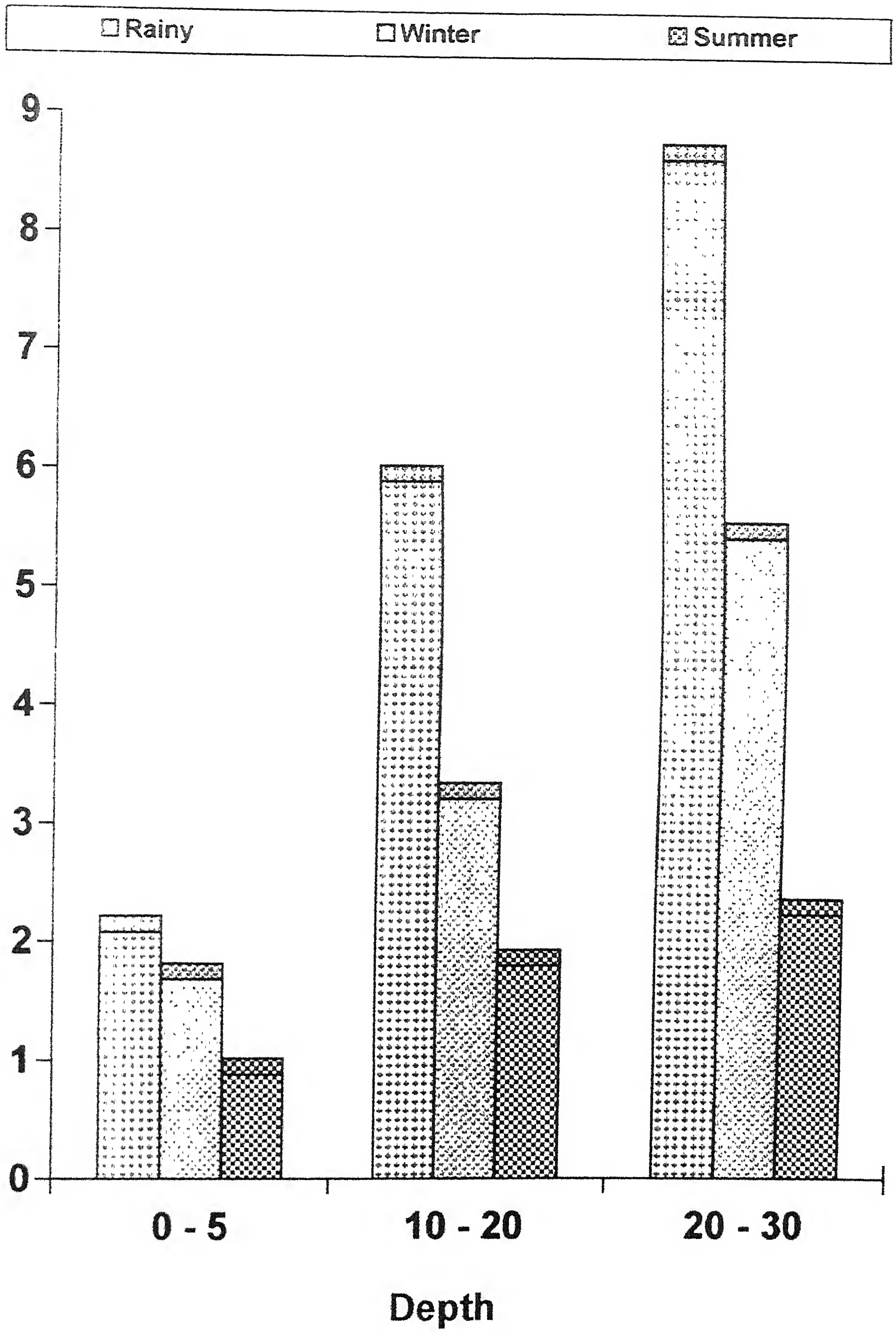
Surface of a leaf. Wooly (1964) stated that a layer of hairs in must cases decrease the air movement next to leaf, and thus creates a greater thickness of still air through which water vapour must diffuse in moving from the Saturday leaf interior to the drier air outside. During the present investigation hairs were presented on both the surfaces of the plant studied.

The survival of plants depends largely upon their capacity for adaptive transformation the course and rate of physiological process during each day and throughout the entire vegetation (Oppenheimer 1951). Amongst different factors which run counter to the natural establishment, soil moisture conditions perhaps plays the most significant role for growth and development of plants. Maximum soil moisture during present study was recorded in rainy season at all depths (fig-4.4). Depletion of soil moisture was recorded in winter and summer seasons.

Lekhak (1983) also reported that winter affect the moisture status of the plants. These findings are supported by the observation of Sen (1972), Sharma (1976), Bohra (1976) Kumar (1984) etc. However, Lekhak (1983) for *T. portulacastrum* reported lowest values of water contents in December (winter season) which is controversial to the results obtained in the present study.

Stomatal movements are greatly affected by environmental factors like presence of soil moisture, CO_2 concentration, light intensity and temperature (Bohra, 1976). He observed maximum stomatal opening in morning and then in noon and least in evening. He correlated this with the fact that with rise of temperature soil moisture depletion occurs, hence more stomatal closure in noon and evening. The test plant studied showed diurnal

Fig 4.4: Seasonal variations in the percentage of soil moisture content from various depths.



and season rhythms which were influenced by their surrounding environment. Higher stomatal opening was recorded in rainy season and least in summer season, which also agrees with the findings of Sharma (1976) and Daiya (1981).

Least stomatal opening during summer season of the test plant can be one of the major factors responsible for drought resistance capacity and higher survival value of plant in the post rainy period. Due to retention of more moisture, the plants could with stand the drought periods.

It is thus concluded that the test plant (*Parthenium hysterophorus*) exhibits eco-physiological differences and show different adaptive features for survival under diverse condition.

4.2.4: Water loss.

Transpiration or water loss (%) from leaves detached, at different times of the day during various seasons in *Parthenium hysterophorus* is presented in figs. (4.5 to 4.7). Observations were recorded during morning, noon and evenings.

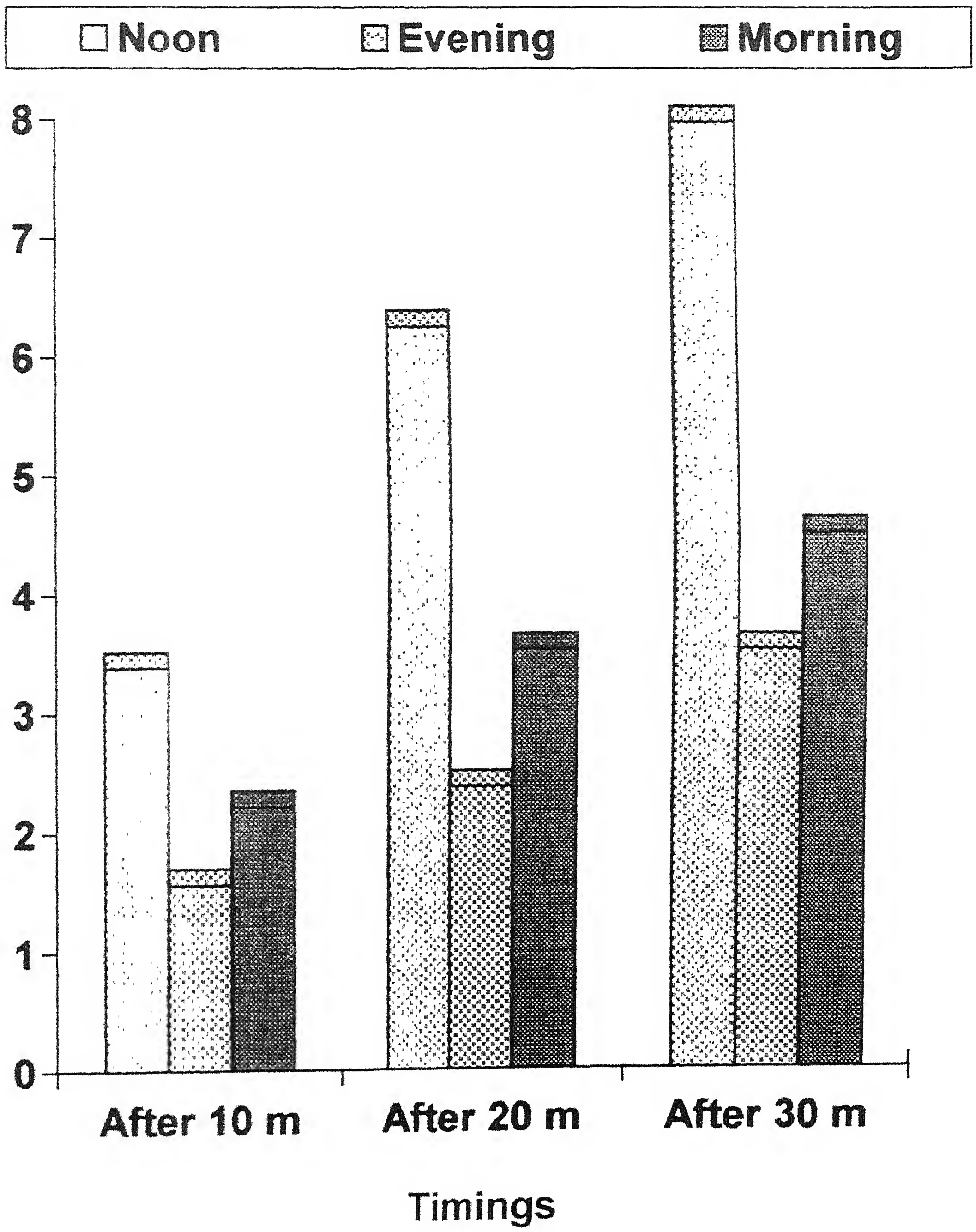
The trend of seasonal variations in the percentage of water loss (on fresh wt basis) as observed, is:-

Rainy: Noon> Morning > Evening – (fig-4.7).

Winter: Noon > Morning > Evening – (fig-4.6).

Summer : Noon> Morning > Evening – (fig-4.5).

Fig. 4.5: Seasonal variations in percentage of water loss in detached leaves after 10,20 and 30 minutes in the morning, noon and evening in *P hysterophorus* in the years 1999-2001 during the summer season.



The significance of water loss by transpiration has been debated for many years (Stark,1968; Sen, 1972). Transpiration also cools the leaf to prevent overheating (Penman, 1948 and Gates 1968). However, it has also been suggested that the main role in cooling of leaves is of no real significance. Transpiration is one mechanism by which plants dissipate heat, but they also loose heat by radiation and convection as the air is cooler than plant (Hoffman & Gates, 1971). In transpiration water moves from the source of high potential in the soil to the sink of low potential in the atmosphere through the vegetation, along a flow pathway which has both flow resistance and capacitance (Jarvis, 1981).

Avoidance plays a major role in drought tolerance, which may involve.

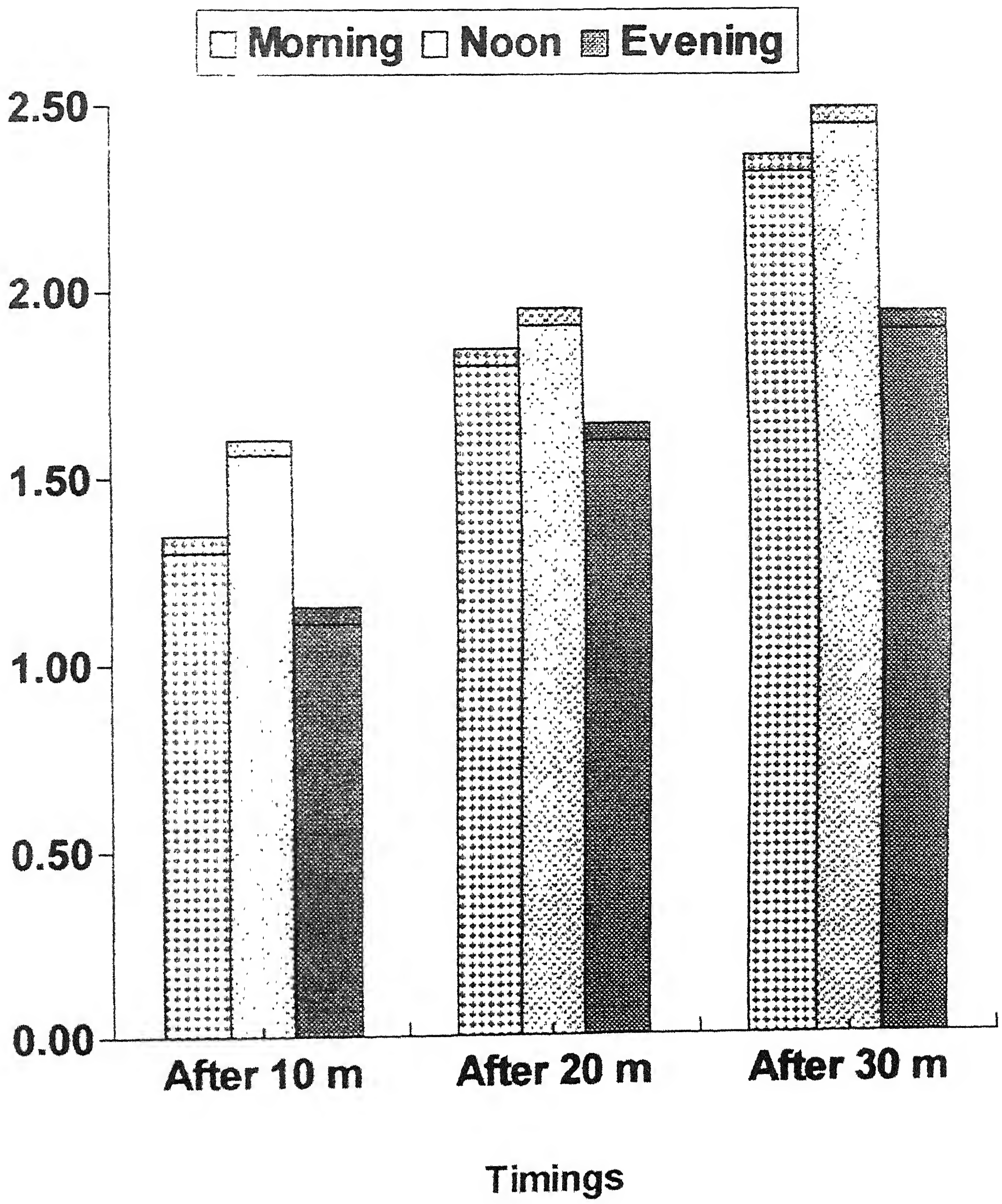
1. Maintenance of root water absorption during periods of low or decreasing soil moisture.

2. Reduction of the energy load on leaves by means of: (a) change in leaf angle; (b) change in leaf reflectivity; (c) increase in leaf transmissivity; and (d) increase in connective cooling.

3. Reduction of foliar water loss by : (a) closure of stomata; (b) delayed stomatal opening; (c) reduction of cuticular water loss; and (d) abscission of leaves and branches.

4. Maintenance of water status in transpiring organs by; (a) internal water storage (i.e. capacitance); (b) osmotic adjustment, and (c) reduction in cell size.

Fig. 4.6: Seasonal variations in percentage of water loss in detached leaves after 10, 20 and 30 minutes in the morning, noon and evening in *P. hysterophorus* in the years 1999-2001 during winter season.



It has been reported that the rate of transpiration under field condtion is largely controlled by the amount of water available in the soil (Bhandari, 1972; Smolander et al; 1975; Sharma, 1976; Daiya 1981 and Kumar, 1984).

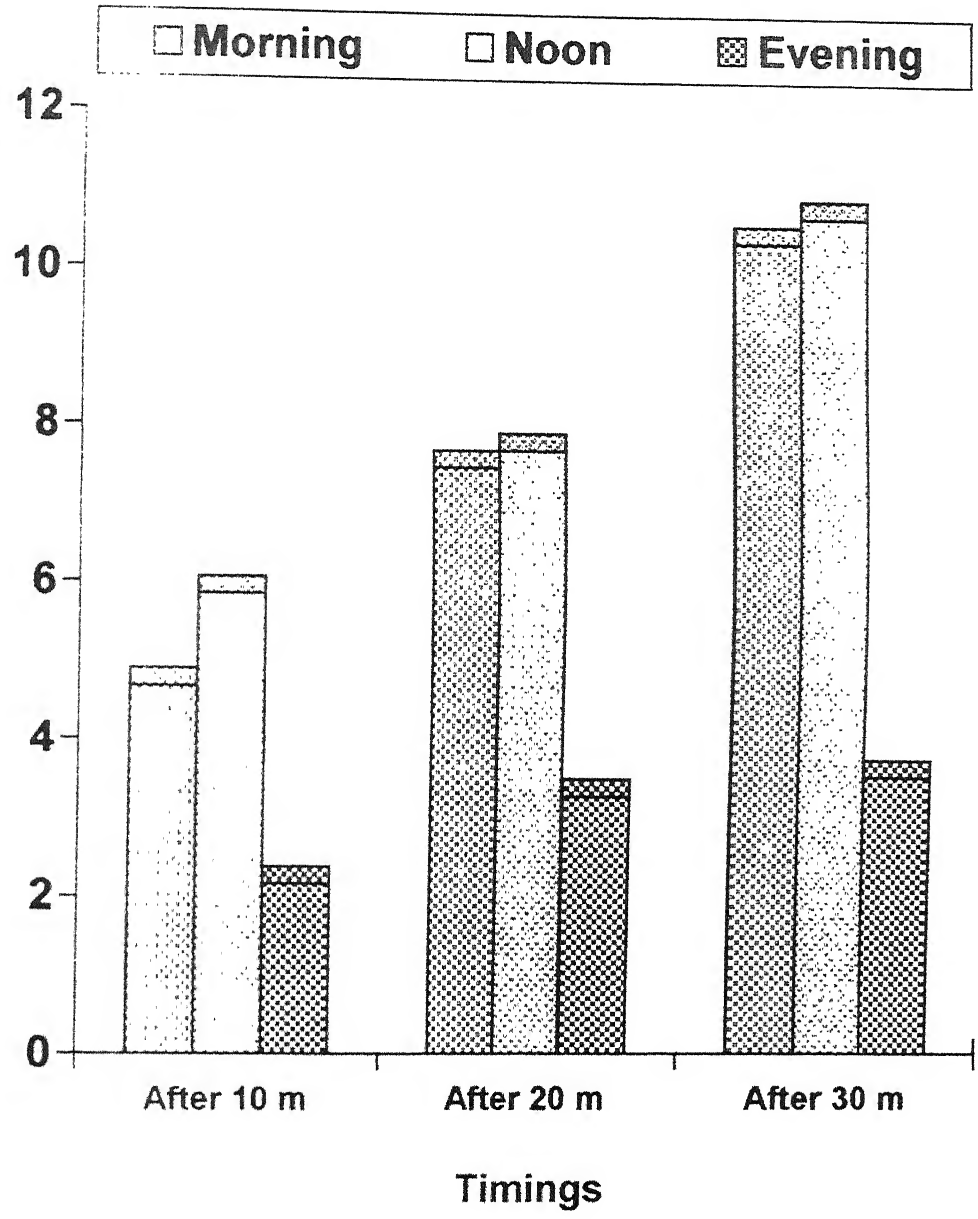
But several other factors have also been reported to affect the rate of transpiration. Under condition of adequate water supply, stomata open in the morning with increasing radiant flux and maintain a relatively constant aperture until radiant flux decline in the late afternoon (Schulze et al.,1972).

This pattern may be modified by shading due to adjacent tree crown or cloud cover, with consequent changes in leaf temperature, water vapour pressure gradient between leaf and air, and therefore, transpiration rate.

Leaf temperature as a drought related character was studied by many workers (Palmer, 1967). Vong & Murata (1977) observed that arid land crop varieties always had higher leaf temperature since their optimum leaf temperature for maximum photosynthetic rate is also higher than the wetland crop species. This suggests that a particular plant species may possess higher optimal leaf temperature which might help in increased photosynthesis.

Stomatal resistance is highly sensitive to changes in leaf water potential. High rate of stomatal resistance is considered to be yet another regulatory mechanism to minimize water loss. According to Turner & Begg (1981) the excess moisture loss at noon hours tends to increase stomatal resistance leading to reduction in transpiration. Plant productivity in arid and semi- arid conditions can be considered as a function of total transpiration and water use efficiency.

Fig. 4.7: Seasonal variations in percentage of water loss in detached leaves after 10, 20 and 30 minutes in morning, noon and evening in *P hysterophorus* in the years 1999-2001 during Rainy season.



In the present investigation it has been observed that transpiration varies with the season in the plant studied. In general, the maximum water loss was during rainy season, which decreased in summer and became minimum in winter season. It was also observed that the rate of transpiration was at its highest during noons followed by mornings, came to least during evening hours.

It is obvious that comparisons of survival cannot provide comparative information concerning water balance and drought tolerance adaptation. However, survival test under water limited conditions provide a relatively simple technique to preliminary screen material for potential genetic differences. In this way, time and effort spent in futile study of more aridness aspect of water relations can be minimized.

4.3: BIO-CHEMICAL STUDY

In any ecosystem there are many environmental factors which affect various metabolic activities and hence, the growth and development of plants in various ways at different times during their life cycle.

Many a factor which influence plant metabolism are: water, temperature, solar radiation and wind velocity. To cope with diversities in these factors, plants possess organized control mechanism which enable them to grow and survive.

Plant body is composed primarily of carbohydrates, proteins, amino acid, nucleotides, lipids and Porphyrines.

4.3.1: Total pigments: -

The results of total pigments (chlorophyll a and b and caretenoids) in the test plant species are given in the table (4.7). The observations revealed

Table 4.7 **Seasonal variations in chlorophyll content (mg g^{-1} F.wt.) in leaves of *Parthenium hysterophorus* during 1999-2001.**

Season	Chl.a	Chl.b	Carotenoids	Total pigments
Summer	3.60±0.11	2.88±0.10	1.85±0.31	1.99±0.30
Rainy	4.28±0.30	2.98±0.21	2.65±0.10	2.53±0.11
Winter	4.06±0.71	2.93±0.50	1.99±0.51	2.28±0.20

Tables 4.8: Percentage of moisture, chlorophylls, total nitrogen and reducing sugars in sun and shade leaves of *P. hysterophorus* during 1999-2001.

Types of leaves	Percentage of moisture	Percentage of chlorophyll	Percentage of total nitrogen	Percentage of reducing sugars
Sun leaves	84.86+4.84	1.46±0.30	5.38±1.24	5.16±1.16
Shade leaves	90.86+5.14	2.15+0.45	4.26±1.18	3.46±0.46

Table 4.9 **Seasonal variation in crude protein (%) and nitrogen (%) (leaves) in *Parthenium hysterophorus* during 1999-2001.**

Seasons	Protein	Nitrogen
Summer	16.87 ± 3.6	2.7 ± 0.6
Rainy	26.25 ± 2.5	4.2 ± 1.0
Winter	20.62 ± 2.6	3.3 ± 1.8

variations in the above parameters during different seasons. The pigment content was highest during Rainy which was followed by winter and the least during summer season.

Under natural environmental condition plants face diverse types of vagaries of climatic and environmental condition. In such cases the survival of plants largely depends on their capacity for adaptive transformation of the course and rate of physiological process during each day and throughout the entire vegetation season (Oppenheimer, 1951). Excess of water loss from plant body often results into dehydration which in turn leads to an increase in the concentration of cell sap and inter cellular fluids. This causes stress on protoplasm and most of the bio-chemical processes are affected adversely because of the imbalance of water.

Chlorophyll is directly influenced by environmental factors like, soil moisture, water stress, temperature, salinity etc. the moisture stress not only affects the amount of chlorophyll but also affect bio-chemical process of the plant. The decrease in chlorophyll content found in leaves of plants, highly fertilized might have been either due to immobilization of added nitrogen sources in the soil or due to increased application of fertilizers (potassium) which might have resulted in deficiency of magnesium, the principal component of chlorophyll synthesis (Sundermoorthy, 1987).

Khanna et al (1980) who worked on the effect of potassium on growth of maize plants reported that in irrigated plants, potassium induced the decrease in chlorophyll content.

The amount of chlorophyll a was found to be greater than the amount of chlorophyll b in the plant studied. Such presence of greater amount of

chlorophyll a than chlorophyll b in higher plants was also reported in spinach, tomato, barley rye, oats, wheat, alfalfa, corn, tobacco, broccolitips, sweet potato, etc. (Stiles & Cocking, 1969; Bhandari, 1977; Sen, 1977b).

During the present investigation the test plant exhibited the highest values, regarding total pigment during rainy season and the lowest during summer season. The decrease in total chlorophyll is mainly attributed to the destruction of chlorophyll a which is considered to be more sensitive than chlorophyll b this decrease in pigment content during summer or winter season, when the water availability is relatively less, may be due to stress induced weakening of a protein pigment lipid complex.

The effect of sunlight and shade on the percentage of moisture, chlorophyll content total nitrogen and reducing sugars are enumerated in table 4.8. From this table it is evident that percentage of moisture content was high in the leaves of shade plants as compared to the sun plants. A reduction in water content took place as the maturation proceeded, due to an accumulation of cellulose. The amount of chlorophyll was also high in shade leaves in comparison to sun leaves, but the percentage of total nitrogen and total reducing sugars were significantly higher in the sun leaves. It is believed that the amount of nitrates under xeric condition is higher as compared to wet ones and that the plants present in such conditions are expected to have higher amount of nitrogen.

Looking at the values in the table the percentage of totalnitrogen is higher in sun leaves as compared to shade leaves. With regard to the percentage of total reducing sugars, the values are high in sun leaves in comparison to shade leave, because of the high percentage of chlorophyll there but the

presence of sunlight appeared to be more important for the production of sugars. Thus, the content of reducing sugars is higher in sun leaves as compared to shade leaves.

It has been known for many years that the stem elongation of many plant species is much more rapid in shade than in full sunlight. The highest elongation rate is usually found at intermediate light intensities. The decreased growth at high light intensities appears to be due to same morphogenic effect of light.

Lockhart (1961) stated that stem of nearly all species elongated more rapidly in partial shade. However marked differences observed in the magnitude of the shade response in different plant species. Stem elongation of bean plants is limited by both gibberellin and photosynthesis. Undoubtedly, photosynthesis provides the basic substrate for stem growth while gibberellin apparently regulates the proportion of available substrate to be channeled into stem elongation and leaf development.

4.3.2: Reducing & Non-reducing sugars:

The seasonal variations with regard to the sugar contents in the leaves of *Parthenium hysterophorus* are presented in the (fig-4.8). In all the cases values of reducing sugars were much higher than non-reducing sugars.

In the present study the highest values were recorded during rainy season followed by summer and winter seasons. Although there was slight variation regarding, insoluble sugars, during rainy and winter seasons.

Slatyer (1967), stated that the proportion of water in plants is far greater than in soil and very small fluctuations within very narrow limits can interfer with active metabolism. It has been observed that leaves of plants subjected to water stress often showed decrease in starch content usually,

which is followed by an increase in sugar content (Levitt,1956; Mohammed et al., 1987).

Singh & Singh (1971), observed a general decreasing trend in all carbohydrate fractions, viz. reducing sugars, non-reducing sugars and starch in tomato plant during water stress. Little (1970) reported fluctuations in total sugars during winter and autumn in the needles of *Abies balsamea*. Bhandari (1972) reported that in *Citrullus colocynthis* reducing sugars were more in rainy months, which declined during winter and summer.

The results of the present study are in accordance with the above findings as the plant species studied exhibited relatively higher values of sugar during rainy season, followed by winter and summer seasons.

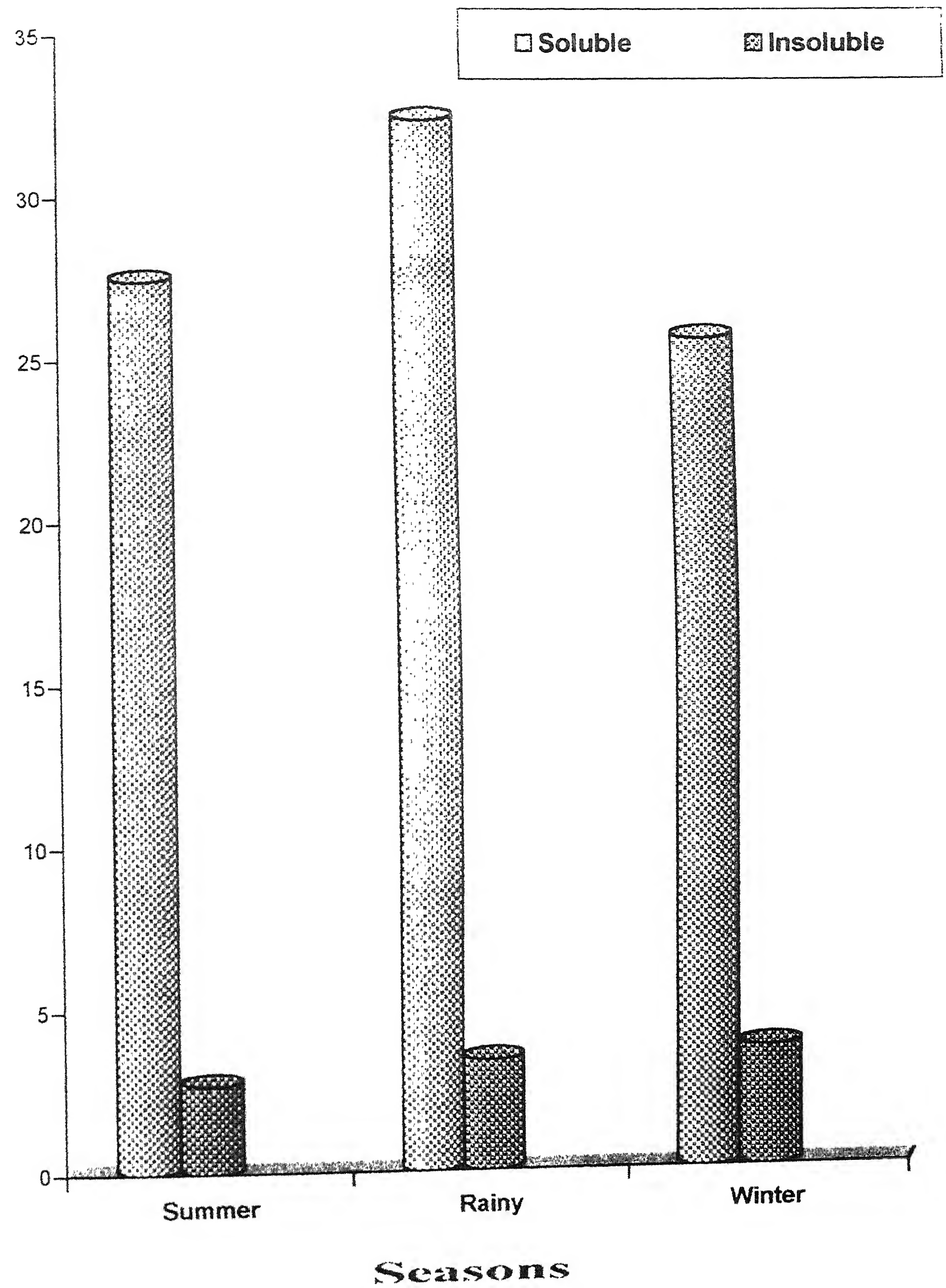
From the present investigation it can be concluded that this particular plant does not get affected much by water stress as far as its metabolic activities are concerned and it is able to maintain itself even under diverse conditions by resuming the bio-chemical and metabolic processes normally and steadily.

4.3.3: Crude Protein:

The seasonal variations in percentage of crude protein and nitrogen in *Parthenium hysterophorus* are given in table 4.9. From the table, it is evident that crude protein contents were maximum when plant water status was higher viz. during rainy season. Maximum protein values were recorded during winter (26.4), followed by rainy (20.6) and summer season (16.8). With regard to value of nitrogen it was higher in winter followed by rainy and summer.

The nutritive pattern of plants are very important; especially in those which are being well established as an important fodder plants. Nutritive values are mainly concerned with protein content of a plant species. Protein is the most

Fig. 4.8: Seasonal variations in total sugar (leaves) (mg g^{-1} f. wt.) in *Parthenium hysterophorus* during 1999-2001.



important constituent of cells from both structural and functional points of view. It is suggested that adequate amount of nitrogen helps the plant to maintain normal metabolism under water and heat stress, which is a major concern for plants surviving under diverse conditions.

The soluble nitrogenous compounds play an essential role in plant metabolism, being the primary products of inorganic nitrogen assimilation and precursors of proteins and nucleic acids. Nitrogen metabolism is affected differently by the type of salinity and intensity of drought and the responses differ in different plant species.

Chakravarty et al. (1970) recorded higher values of protein in *Tribulus terrestris*, *Tephrosia purpurea* and *Cyprus rotundus* during rainy season which were substantial higher as compared to winter and summer.

During the present investigation, the plant studied showed the higher values during the rainy season, lesser in winter and least in summer which confirms the above findings. The decrease in protein content can be attributed to enhance the proteolytic activity, which result into the accumulation of amino acids (Rao, 1981). Protein synthesis and turnover in growing plants play a pivotal role in metabolic regulation, which provides a way for varying enzymatic component during response to water stress.

4.4: MANAGEMENT STUDIES

To control this ever green menace is the crying need of the hour as it has posed a great threat to our entire eco-system, leading to a myriad of hazards to both flora and fauna. This plant has put a great challenge to the scientists all over the world as far as its eradication is concerned. Having this

perception in mind a management strategy, involving all the possible control measures, was formulated to overcome this problem. A detailed account of the methods tried is as under

4.4.1: Manual method:

Under this weed was removed from a certain area by cutting the aerial portion and pulling out the plants. But it was found that after removal of the weed, new plants sprout from left over roots and stump. Therefore this method is uneconomical and impracticable because of the prevalance of the weed covering large cultivated wastelands, roads and railway tracks. During the present study it was observed that number of new plants sprouted after the removal, was more in case of plants removed by cutting of the aerial part of weed, than those, which were removed by pulling out of the whole weed.

Data recorded on the emergence of the new plants are presented inthe table-(4.10) From the table it is evident that maximum reduction in emergence of the new plants was obtained when the whole plants were pulled out. In the present investigation it was also observed that new plants were emerged earlier in case of plants removed by cutting method where as a delayed emergence was observed in case of plant removed by putting out.

Thus, it can be concluded that if the weed is to be removed by conventional method, it should be done by pulling out of the whole plant.

4.4.2: Chemical method:

Results of effect of chemicals on suppression of the weed viz. Round up (glyphosate) and 2,4-D with different doses are presented in the table (4.11). From the data recorded it is evident that Round up (glyphosate) has

Table 4.10: Effect of manual method consisting of cutting of aerial part and pulling out of the whole plant on the emergence of new plants of *Parthenium hysterophorus*.

No. of plants (in m^2) before removal	No. of new plants (in m^2) emerged after 35 days of removal	
	Removed by cutting the aerial part	Removed by pulling out of the whole plant
36.62 ± 3.41	20.34 ± 1.68	16.87 ± 1.03

Table 4.11: Effect of round up and 2, 4-D on suppression of *Parthenium hysterophorus*.

Herbicide	Dose (kgai/h)	Visual toxicity (Mortality/test plot)
Roundup	1.0	90.0 ± 2.60
Roundup	1.5	96.6 ± 3.84
Roundup	2.0	98.0 ± 2.87
2,4-D	1.0	73.8 ± 2.19
2,4-D	1.5	80.0 ± 3.67
2,4-D	2.0	84.4 ± 2.53

supremacy over 2,4-D as far as suppression of *Parthenium* weed is concerned with maximum suppression obtained at 2.0 kgai/h dose of Round up where in 98% mortality of *Parthenium* plants was seen in the test plots as compared to other doses of the same treatment. Whereas amaximum of 80% mortality was recorded in case of 2,4-D sodium salt with the concentration of 2.0 kgai/h. lower doses of both these herbicides exhibited lower mortality rate.

Researches on chemical control of *Parthenium* in India gained momentum since eighties. Bromacil, diuron and terbacil @ 1.5kg ai/h were found effective as herbicides. (Kanchan & Jayachandra, 1977). Diquat 0.5 kg/h in 500 l spray effectively controlled *Parthenium* at all growth stages

(Dhanraj & Mitra, 1976). Spraying of 2 kg 2,4-D sodium salt or MCPA in 400 l of water controlled the growth of *Parthenium* seedlings. On the basis of two years research Balyan et al (1977) gave concrete recommendations for control of *Parthenium*. They also advocated the supremacy of chemical control over other control measures on ground of quick relief, time saving and cost effectiveness.

During the present investigation, findings recorded are in agreement of the above results.

The results with regard to effect of Round up and 2,4-D sodium salt on chlorophyll (a & b) caretenoids and pigment of *Parthenium* plant are given in the table-(4.12). The data recorded in the table-(4.12) reveal the decreasing trend of pigments (mg/g) with increasing trend of doses of both the herbicides viz round up and sodium salt (2,4-D) in comparison to the control. However, the former is more toxic as compared to the latter. Least

amount of pigment was recorded in the leaves of *Parthenium* plant at 2.0 kgai/h dose of Round up in comparison to the remaining two doses of the same herbicide after six days of spray. From the data it is obvious that these chemical cause disintegration of chlorophyll in the plant species studied during the investigation.

Therefore in the light of the above study it may be concluded that rate of disintegration of pigments was more in higher doses of herbicides sprayed on the *Parthenium* plants.

4.4.3: Biological approach:

4.4.3.1: Fungal control: The data regarding effect of *Fusarium oxysporum* (100g/l suspension) on growth and seedling mortality of *Parthenium hysterophorus* are presented in the table-(4.13). From the data recorded, it is revealed that seed inoculation with *F. oxysporum* caused nearly 32 percent seed rot and 76 percent seedling mortality as it is evident from the table (4.13). The fungus grow on the surface of the seed and got established with in 40 hours of inoculation and infected roots of the plant. Root growth was inhibited and abnormal seedlings were developed and survived for 15 days after inoculation. The fungus also attacked the growing point of the seedling which turned light brown in colour. The fungus could affect the whole surface of the seedling.

Fusarium pallidorseum (Cooke) sace has been explored as a biocontrol agent to control the *Parthenium* weed (L.P. Kaurav; A Chile;& V.M. Bhan, 1998). They have opined that spray of the fungus @ 100, 150 and 200 g/l of water could reduce seed germination, seedling growth, plant height by 35 percent, branching by 29% and number of flowers by 38%. Soil

Table 4.12: Effect of round up and 2,4D on chlorophyll (a & b) and carotenoids of *Parthenium hysterophorus*.

Herbicide	Dose (kgai/h)	Chlorophyll (a) (mg/g)	Chlorophyll (b) (mg/g)	Carotenoids (mg/g)
Roundup	1.0	6.98	1.45	1.60
Round up	1.5	5.89	0.96	1.10
Roundup	2.0	2.45	0.79	0.93
2, 4-D	1.0	7.86	1.51	1.73
2, 4-D	1.5	4.58	1.02	1.26
2, 4-D	2.0	3.47	0.84	1.04
Control	-	9.32	3.56	2.65
C.D. for treatment				
C.D. for dose		0.496	0.1307	0.2058
C.D. for interaction		0.992		

inoculation, spray and seed treatment reduced seed germination and growth of *Parthenium*.

During the present investigation *F. oxysporum* was used as a bio-control agent and findings thus obtained exhibited that 100g/l water of the fungus suspension could reduce the seed germination and seedling mortality rate by 32% and 76% respectively. It, therefore, can be concluded that the fungus species may be used as a biocontrol agent, under field condition, to check the growth of *Parthenium* weed.

Observations, regarding effect of different methods of inoculaion (spray, seed treatment and soil inoculation) on germination of *Parthenium hysterophorus* in pots (100 seeds sown), were recorded in the table (4.14). From the data presented in the said table it is apparent that seed inoculation, soil inoculation and spray of the fungus on the seed caused seed rot and seedling mortality. It is apparent from the observations recorded that spray on seed is effective marginally than that of seed inoculation by mixing and soil inoculation, as maximum values with regard to the percentage reduction in germination were recorded when the seeds were subjected to the direct spray, (46.4 %) However, all the three methods tried could reduce the germination of *Parthenium* seeds, as compared to the control, viz. 28.0 & 21.0 respectively

Thus from the results obtained in the present study, it can be concluded that the tried fungus mycelium suspension is effective as far as biological control of *Parthenium* plant is concerned.

Observation on the effect of spray (100 g mycelium/l water) of *Fusarium. oxysporum* at different days after sowing of *Parthenium* (1999 -2001) are

Table 4.13: Effect of *F. oxysporum* (100g/l suspension) on growth and seedling mortality of *Parthenium hysterophorus* in petriplates.

Treatment	% Germination	% Seedling mortality
Inoculated	68.0 ± 4.21	76.0 ± 3.96
Control	84.0 ± 4.96	2.0 ± 0.02

Table 4.14: Effect of different methods of inoculation (spray, seed treatment and soil inoculation) on germination of *Parthenium hysterophorus* in pots (100 seeds sown).

Treatment	Treated no of seeds germinated	Control no. of seeds germinated	Percentage Reduction in seeds germination.	Percentage Seedling dead
Spray on seed	15.0 ± 2.53	28.0 ± 3.48	46.4 ± 2.16	26.0 ± 1.64
Seed inoculation by mixing	13.0 ± 1.87	21.0 ± 2.65	38.0 ± 3.6	24.0 ± 1.32
Soil inoculation	19.0 ± 2.10	34.0 ± 2.93	44.1 ± 2.84	21.0 ± 1.3

illustrated through the fig (4.9-4.11). From the figures it is clear that the spray of 100g mycelium per litre of water could not reduce much plant height, number of branches and no. of flowers. Maximum reduction in height (8.7%) was in spray after 25 days. Maximum reduction in number of branches per plant (16.3) was observed at spray after 25 days and maximum reduction in number of flower per plant (24.2) was recorded when sprayed after 35 days as compared to the control. Thus, it may be concluded that the spray of the fungus is effective to control parhtenium plants; however more work in this field is needed.

Field experiments were conducted during the years of 1998-2001 so as to evaluate the effect of the spray of different amount of inoculum of *Fusarium oxysporum* at vegetative stage, before flowering and after flowering stages. Results thus obtained are presented in the table (4.15). It is revealed from the data recorded in the table (4.15) that the spray of 100, 150 and 200g wet mycelium per litre of water at vegetative stage and before flowering stage could reduce plant height, number of branches and flowers per plant but maximum reduction in these parameters was obtained when *Fusarium oxysporum* was sprayed at 150-200g per litre of water at vegetative and before the flowering stage. When the efficacy of treatment was analysed in terms of its effect on different parts of the plant viz- height, branching and flowers it was noted that flowers appeared were observed to be maximum sensitive as it is evident from the data recorded.

Fusarium pallidorseum has been tried as a biological control agent. By L.P. kaurav, A. chile and V. M. Bhan 1998. They have opined that the sprayof *Fusarium pallidorseum* can reduce the growth (plant height, branching and flowers) of *Parthenium hysterophorus.*

Fig 4.9: Effect of spray (100g mycelium/l water) of *Fusarium oxysporum* on heights at different days after 1 month of sowing of *Parthenium hysterophorus* (during the years 1999 to 2001).

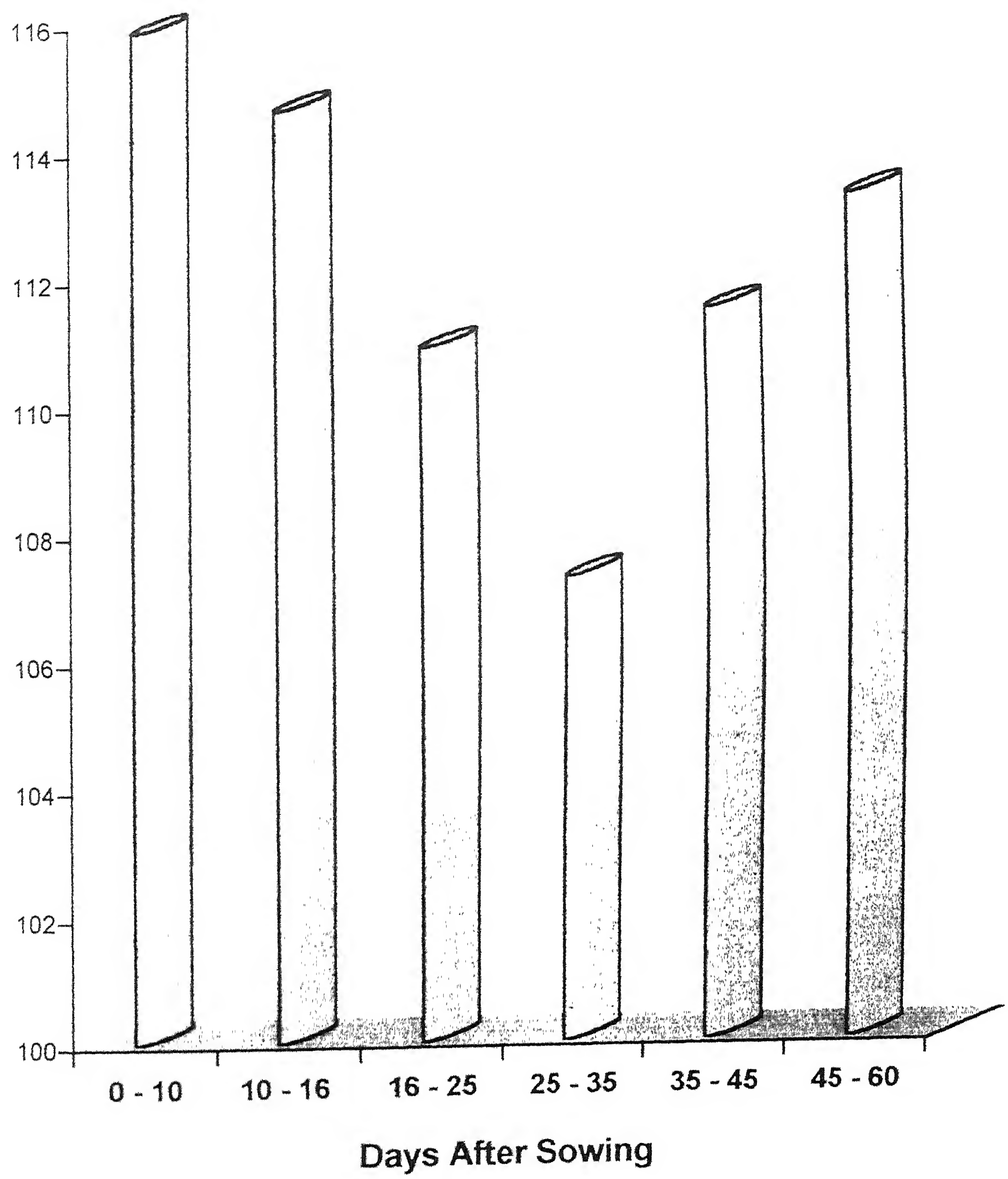


Fig 4.10. Effect of spray of (100g mycelium/l water) of *Fusarium oxysporum* on numbers of flower per plant at different days after 1 month of sowing of *Parthenium hysterophorus* (during the years 1999 to 2001).

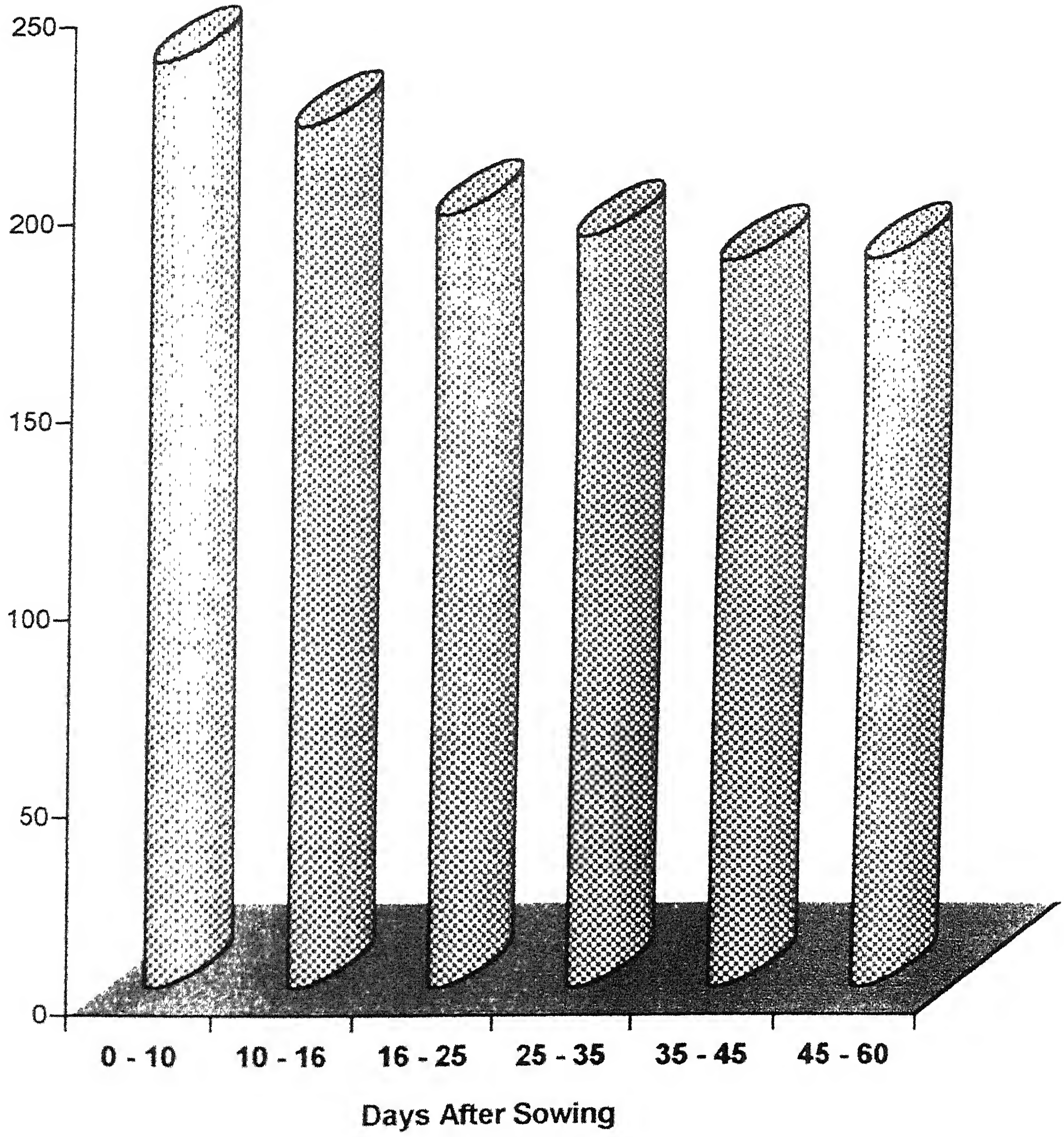
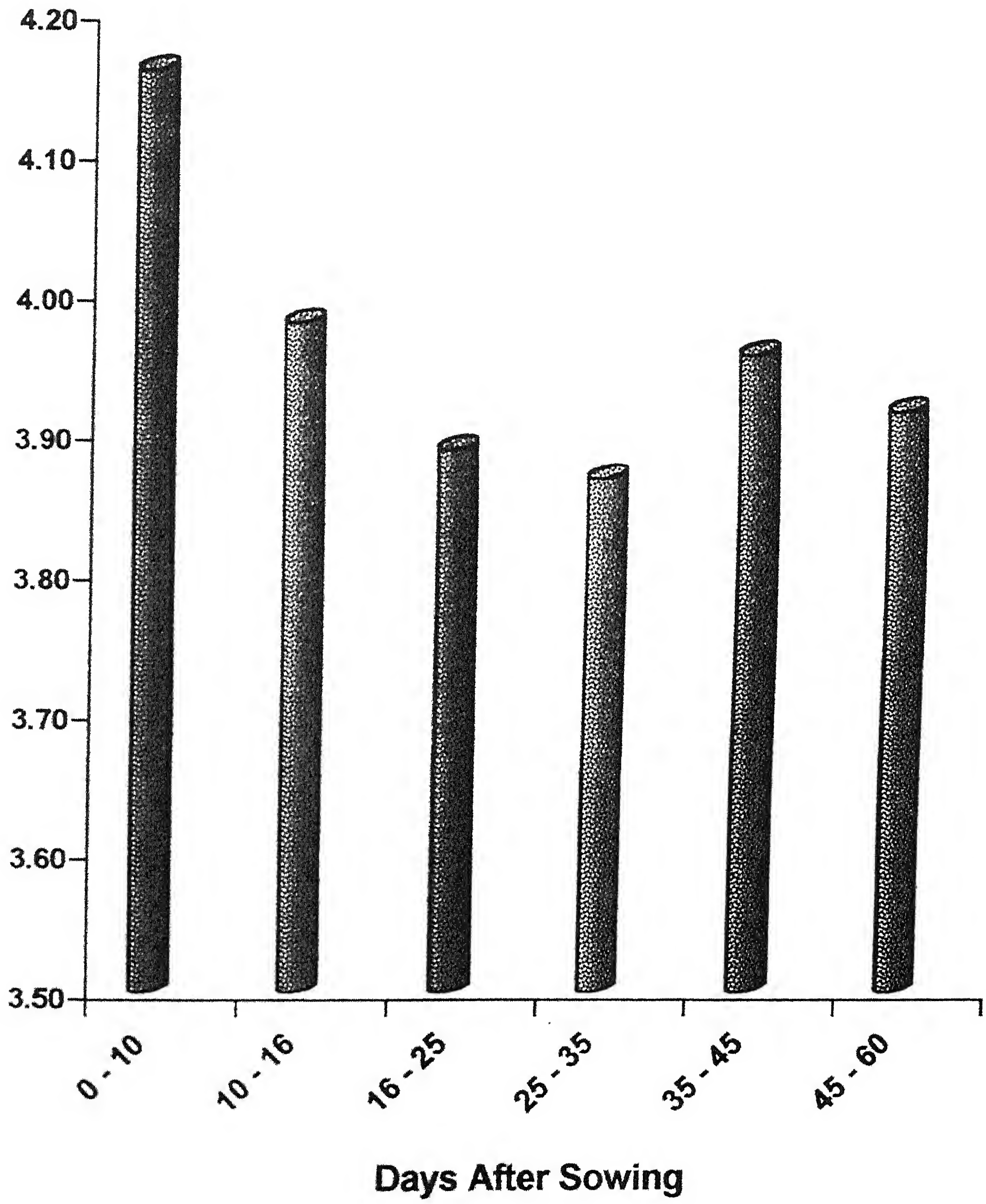


Fig 4.11: Effect of spray (100g mycelium/l water) of *Fusarium oxysporum* on numbers of branches per plant at different days after 1 month of sowing of *Parthenium hysterophorus* (during the years 1999 to 2001).



In the present investigation it has been observed that the spray of *Fusarium oxysporum* could reduce the parameters recorded in the table. Therefore it may be concluded that this fungus can be used as a biological control agent to control *Parthenium* plants upto certain extent.

4.4.3.2: Use of botanical agents (BAs)

The data on the effect of competitive plants on the growth and flowering of *Parthenium* recorded in the table (4.16) reveals that the *Parthenium* population was substantially lower under *Cassia uniflora, Abutilon indicum* and *Tagetes erecta* as against control (*Parthenium* only). However *Tagetes erecta* reduced the *Parthenium* dry weight by 64.0 percent, while *Abutilon indicum* and *Cassia uniflora* caused about 67 and 71 percent reduction in dry weight, respectively. The seed rates of competitive plants did not show much variation in their effect on *Parthenium* population and dry weight. Similar trend was observed in reduction of flower heads of *Parthenium* by the above said competitive plants. Maximum reduction was obtained in case of *Cassia uniflora* followed by *Abutilon indicum* and then *Tagetes erecta*. The young seedlings of *Cassia uniflora* and *Abutilon indicum* are larger than those of *Parthenium*, with well developed root and shoot systems. This advantage enables them to suppress the vegetative growth of *Parthenium*, delay flowering and reduce the number of capitula as well as seeds.

As an effective alternative to conventional biological control methods, exploitation of dominant crop and plant species to replace *Parthenium* by their vigorous growth or allelopathic activity has been successfully demonstrated by Desai and Bhoi (1991) and Mahadevappa and Joshi (1985)

Table 4.15: Effect of different amount of inoculum of *Fusarium oxysporum* at different growth stages of *Parthenium hysyterophorus*.

Treatment	Height/plant (in cm)	Branching / plant	No.of flowers / plant
(A) Vegetative stage			
100g mycelium/l	62.43	4.60	141.58
150g mycelium/l	60.33	4.32	130.16
200g mycelium/l	55.74	3.86	117.85
Control	64.60	4.98	183.63
C.D.	1.4418		
(B) Before flowering			
100g mycelium/l	59.43	3.80	186.33
150g mycelium/l	54.87	3.61	174.69
200g mycelium/l	52.36	3.12	133.57
Control	63.23	4.10	201.67
C.D.			15.2700
(C) After flowering			
100g mycelium/l	63.86	3.83	176.26
150g mycelium/l	61.48	3.57	165.70
200g mycelium/l	63.56	3.48	131.61
Control	64.36	4.06	195.66
C.D.			11.4140

whose attempts with *Stylosanthes hamata* and *Cassia uniflora* have produced encouraging results. *Cassia uniflora*, though suppress the *Parthenium* growth, its establishment is not uniform over the biological regions.

In the present study results observed may also be attributed to the fact that the allelopathic effect released by the roots of the test plants might have acted as an added advantage to them apart from the physical. The competitive work on identifying the active ingredients in the roots may be taken up for future studies. In this direction the present investigation has indicated the possibility of using the tested competitive plants species to manage the *Parthenium* menace in unattended larger areas.

4.4.3.2.1: Effect on Plant Extracts on Germination of *Parthenium hysterophorus*.

Observations, on the effect of plant extracts on percentage germination, seed vigour radicle and plumule length of *Parthenium hysterophorus*, are presented in table (4.17). The data recorded in the table (4.17) depict that 92 percent germination of seeds of *Parthenium* was observed in the control. In comparison, only 27 percent of seeds germinated in 100 percent concentration of *Cassia uniflora* which was increased to 74% in 25 percent concentration. In the extracts prepared from *Abutilon indicum* the minimum germination was 29% at 100 percent concentration and maximum was 79.1 at 25 percent concentrations, likewise in *Tagetes erecta* extract the minimum value regarding germination was 34 percent and maximum was 84% in 100 and 25% concentration, respectively.

Table 4.16: Effect of competitive plants (BAs) and their density on the growth and flowering of *Parthenium hysterophorus*

Competitive Plants (BAs)	Seed rate (kg h)	Plant popn. (000 h)	*Partheni um* popn. m²	*Parthenium* dry wt.		*Parthenium* flower heads	
				g/pl	% redu- ction	Plant^{-1}	% redu- ction
Cassia uniflora	1.5	27.6	18.23	7.6	69.3	980	59.6
Cassia uniflora	2.0	36.2	17.65	6.9	72.1	769	63.3
Cassia uniflora	2.5	45.6	15.87	6.7	72.9	683	71.9
A. indicum	1.0	33.8	20.61	8.3	66.5	989	59.3
A. indicum	1.5	49.6	19.45	7.8	68.5	967	60.2
A. indicum	2.0	65.7	18.73	7.6	69.3	874	64.0
Tagetes erecta	0.4	82.4	24.63	9.4	62.2	1186	51.2
Tagetes erecta	0.5	103.6	22.16	8.6	65.3	1161	52.2
Tagetes erecta	0.6	123.6	21.86	8.4	66.1	1089	55.2
Control (*Parthenium* only)	-	-	76.54	24.8	-	2431	-
C.D.					5.7587		5.8563

Effect of extracts on seed vigour of *Parthenium hysterophorus*

In control, the seed vigour was found to be the highest at 8.16 compared to it the minimum value was 3.24 in the plants growing in 100 percent concentration of *Cassia uniflora* extracts. Whereas in the extract of *Abutilon indicum* the minimum value was 3.86 and maximum 7.63 in 100 percent and 25 percent. concentration of the plant extract, respectively.

Similarly the minimum value with regard to seed vigour was 4.72 percent in 100 percent concentration of *Tagetes erecta* extract.

4.4.3.2.2: Effect of Plant extracts on radicle and plumule length of *Parthenium hysterophorus.*

The plants growing in control were quite healthy with root and shoot system. Their mean radicle and plumule length was 1.63 and 2.1 cm respectively. Just like, percent germination and seed vigour, the mean radicle and plumule length was minimum in 100 percent extract concentration of *Cassia uniflora* and maximum in 25% concentration of the same extract.

Same trend was observed in the extract concentration of *Abutilon indicum* and *Tagetes erecta* on radicle and plumule length of *Parthenium* seed.

The present work is one such step where extracts prepared from the tested plant species were used to study their effect on various growth parameter studied hereunder.

Results revealed that the extracts from the BAs have some potential to inhibit the germination and growth of *Parthenium hysterophorus.*

Table 4.17: **Effect of root extracts of BAs on percentage germination, seed vigour, radicle and plumule length of *Parthenium hysterophorus*.**

Extracts of the BAs	Percentage concentration	Percentage germination	Seed vigour	Radicle length (cm)	Plumule length (cm)
Cassia uniflora	25	74	6.65	1.23	2.04
	50	61	5.89	1.01	1.95
	100	27	3.24	0.87	1.68
Abutilon indicum	25	79	7.63	1.30	2.18
	50	68	6.78	1.23	2.07
	100	29	3.86	1.01	1.73
Tagetes erecta	25	84	7.97	1.41	2.37
	50	73	6.94	1.36	2.15
	100	34	4.72	1.13	1.86
Control	--	92	8.16	1.63	2.45
C.D. for treatment		11.3242	0.6576	0.0896	0.1539
C.D. for dose		9.8070	0.5695	0.0776	0.1333
C.D. for interaction		19.6141	1.1390	0.1553	0.2666

As this weed is found to be grown under monocultures of various tree plantations, it is quite clear that complete eradication of this weed using the allelochemicals from the test plants is not possible however, these natural chemicals can be used as a supplement with the chemical weedicides, decreasing their high doses to a considerable level. Kohli and Rani (1992) observed that the herbicidal action of synthetic herbicide glyphosate was increased considerably when mixed with allelochemicals.

Similar results were obtained by Dhawan et al. (1995 a and b) from the leaf extracts of some trees like *E. tereticornis*, *Ziziphus jujuba*, *Aegle marbelos*, *Azadirachta indica* etc. they found that there was cent percent inhibition in germination of seeds of *P. hysterophorus* in the aqueous extracts of the trees of *E. tereticornis*, *A. marmelos* and *A. indica*. The effect of leaf extracts obtained from *E. tereticornis* on the germination of *P. hysterophorus* was studied by Kohli et al. (1998).

Thus, to obtain the target of complete eradication of *P. hysterophorus* or any other weed a suitable combination of allclochemicals and weedicides can be obtained which is not only effective but also environment friendly. More efforts are to be made in this regard.

An integrated approach, encompassing of various possible methods viz. mechanical, chemical and biological methods (Fungal and BAs), was made under the present investigation so as to evaluate its effect on the management of *Parthenium* weed. Observations, recorded, are presented in the table (4.18). From the adaptive research carried out in the present study in and around Allahabad city for 3 consecutive years from 1998, involving large areas and employing different control methods individually and in

Table 4.18: Effect of integrated approach (manual, chemical & biological) on percentage suppression of *Parthenium hysterophorus* (during 1999 to 2001).

S.No	Treatments	Dose	Percentage suppression (Mean value of 3 years)
1	Manual + chemical (glyphosate)	0.75 kgai/h	97.86
2	Manual + *Cassia uniflora*	1.5 kg seed/h	56.38
3	Manual + *Abutilon indicum*	1.5 kg seed/h	52.43
4	Manual + *Tagetes erecta*	0.5 kg seed/h	51.46
5	Manual + *Fusarium oxysporum*	150 g/lmycelium	57.84
6	Manual + *Cassia uniflora* + *F. oxysporum*	1.25 kg seed/h + 100 g/l mycelium	60.16
7	Manual + *Abutilon indicum* + *F. oxysporum*	1.5 kg seed/h + 100 g/l mycelium	58.96
8	Manual + *Tagetes erecta* + *F. oxysporum*	0.4 kg seed/h + 100 g/l mycelium	51.69
9	Manual + *F. oxysporum* + chemical	100 g/l mycelium + 0.5 kgai/h	98.72
10	Control (Manual)	----	48.63
	C.D.		9.2665

combination has obviously demonstrated that only an integrated approach now termed "Integrated *Parthenium* weed management. (IPWM)" can be effective in suppressing the weed. If a concerted effort is made adopting IPWM, the results will be visible in the second year and in the third year the *Parthenium* population can be brought down to a considerable limit. From the data it is clear that though chemical methods can be employed to suppress the weed but its harmful effect on soil and on other natural flora and fauna apart from it being a costly approach need to be combined to other method to over come this problem. With regard to biological methods viz. fungal and botanical agent it is learnt that the fungus species tried, when combined with manual and BAs could result in maximum suppression of the weed. As far as competitive plants are concerned it is apparent that all the three species of BAs viz. *Cassia uniflora*, *Abutilon indicum* and *Tagetes erecta* do have some potential to suppress the weed individually and in combination as illustrated in the table 4.17 & 4.18. However, *Cassia uniflora* is capable of suppressing the weed to a maximum level as compared to other species tried. From the table it is also clear that when chemical method is combined with other methods to control the weed, the dose of the chemical is reduced to almost half where results obtained are more encouraging as compared to individual methods.

On the basis of the results obtained with regard to the effective management of this obnoxious weed an IPWP strategy can be formulated involving the following steps for better results. (i) maintenance of natural biodiversity (ii) in places where cleaning and exposing of soil is unavoidable, planting of botanical agents should be done at the start of rainy season and promoting their growth to insulate such opened up soils against

invasion by *Parthenium* (iii) Plants which may grow alongwith BAs are to be removed in the first one or two years, so that BAs establish well and perpetuate up on their own. In the case of gardens, flowerbeds, lawns and intensively cultivated agricultural fields, manual removal can be taken up, (v) In situations wherein the above said methods can not be adopted it can be temporarily suppressed through herbicide application. The first two methods viz. manual removal and herbicide applicationcan also be integrated initially with biological methods in order to achieve desired results more quickly. To achieve the target enshrined in the IPWM strategy there are some specific operational tips that need to be focussed while laying down the said stategy.

1. Mark the boundary of the area to be treated.
2. Maintain the existing vegetation except the*Parthenium* weed.
3. Uproot the *Parthenium* plants, if any.
4. In open soils, where there is no vegetation open shallow furrows of about 2.5 to 3 cm deep and sprinkle seeds of the BAs at fixed rate. Furrow opened 22.5 cm apart are optimum for the purpose.
5. When the seeds germinate after rains, encourage the growth of plants by uprooting only *Parthenium*.
6. Pay special attention to protect and promote the growth of plant species which have been grown to suppress the weed.
7. Uproot *Parthenium* plant at regular intervals so as to enable BAs to put up full growth.
8. Once this is accomplished, BAs perpetuate on their own and there will be no need to plant them again unless the soil is scraped to take out self sown seeds of BAs.

9. The sowing of seeds can be taken up just before the onset of rains or after the first rains.
10. It is to be ensured that seeds of BAs collected and stored are scarified for breaking dormancy before sowing.

Therefore in the light of the present study, it can be said that the IPWM strategy though a slow process can minimize the *Parthenium* population more effectively, might be at slow level initially but if persistent efforts are made in the same directions, this one of the most obnoxious weed of this country can be contained to a considerable level without compromising at the cost of the natural ecosystems and our environment, apart from being more economic, safe and long term management.

CHAPTER – V

SUMMARY

AND

CONCLUSION

SUMMARY AND CONCLUSION

The present study entitled "**An investigation on the effect of environment complex on *Parthenium hysterophorus* L., its adaptive strategies and management through non-chemical practices**", gives an account of *Parthenium hysterophorus* L. plant, regarding its general introduction, Phenology, seed morphological studies, seed viability & germination behaviour, germination velocity index, leaf morphology, water relations, stomatal studies, transpiration or water loss, with regard to bio-chemical studies: nitrogen, protein, soluble & non-soluble sugars chlorophyll content and management of *Parthenium* plant with several methods viz. manual, chemical, biological and withan integrated approach more appropriate to pronounce as IPWM strategy. The studies were conducted for the three consecutive years, i.e. 1999 to 2001 and the results presented here are the means of three years.

The present study is a primary step towards the phenological events in the life cycle of *Parthenium hysterophorus.* Field observation led to the discovery of the diversities in various phenomena such as flowering, fruiting and leaf shedding, etc. Plants studied were seen throughout the year. Three to four generations are produced per year by this plant. An important feature of this plant was the formation of rossette with dark green, pinnectisect radical, spreading on the ground forming mats and not allowing any vegetation underneath. Vigorous densities vegetation and growth in this plant were observed during rainy season. Rossette formation in plant was observed when there is extreme cold and hot (Nov-Jan & May-June, respectively). It is presumed that this enables the plant to tide over the

unfavourable conditions thus ensuring survival. Leaf shedding in the plant takes place during May-June when there is extreme temperature in the region. Seed dispersal and maturation take place usually in the months of June, July and August and after this seed dispersal begins.

Seed morphological characters in the plant studied are very important because it is directly related to its survival. Very tiny and light seeds collected from the plant ensures its easy dispersal from one place to another and even to a remote places. Variations in the color and shape were observed as it varied from dark grey to brown with dorsiventrally flattened structure. Variations particularly in size and weight also exist in the given species. Thus it can be concluded that the variability of seeds in the plant species is a significant step to put toward those species and eco-types ahead from others for better, establishment and successful survival. Germination velocity index (GVI) acts as very important parameter to sort out the fastest germinating seed type in the same species.

In the present study an observation was made on viability and germinability of *Parthenium* in which seeds of two types viz.A-fresh seeds and B. 6-8 month old seeds stored were tested and the results thus obtained showed more percentage of germinability in case of stored seeds as compared to the fresh seeds. With regard to viability, it was maximum rate in fresh seeds. Germination velocity index (GVI) in the plant exhibited maximum in rainy season (3.65) minimum in winter (2.87) and least (1.96) in the summer season. Maximum seed germination in rainy season in and viability for a longer period in the seeds of *Parthenium* ensure its dense population during the rainy season, followed by winter season when there is sufficient moisture in the soil. This indicates that buried *Parthenium.*, seeds can remain viable

for a longer period. This has implications for future management of the weed, particularly cultivated areas where seed burial occurs regularly.

In the plant species studied maximum area (mm^2) infested was recorded during rainy season followed by winter and summer seasons which got increased after each season with increased leaf insertion level from the apex.

In the present study, stomates were found on both the surfaces of the plant and maximum stomatal densities were recorded during the summer season There was not much variations as far as stomatal size on surface is concerned, although maximum number. of stomates were found on the upper surface. Percentage of stomatal opening was observed in the following order:-

Rainy	:	Morning > Evening > Noon.
Winter	:	Morning > Noon > Evening.
Summer	:	Evening > Noon > Morning.

Maximum stomatal opening in percentage, irrespective of day hours, was observed on the upper surface of the plants studied. Plant hairs were also present on both the surfaces of the leaves with the more hair densities on upper surface as compared to the lower one.

Plants hairs have been linked either directly or indirectly to increased water use efficiency as in most cases they decrease the air movement next to the leaf, and thus create a greater thickness of still air through which water vapour must diffuse in moving from the saturated leaf interior to the drier

air outside. Highest osmotic potential (OP) was observed in July– August (-28.34) which continued to decrease up to November – December (- 38.43 bars) and again a gradual decrease was observed in the following month till May-June (-35.87) except in the month of January – February in which it rose slightly (-31.67). The maximum value of OP recorded during monsoon month of July-August when there is plenty of moisture in the soil.

The percentage plant water content (PWC) varied from 171.58 to 199.85. The highest value for (PWC) was recorded during July-August and it was lowest during May-June in the plant studied from these observations it can be concluded that high PWC is related with more soil moisture content which is obtained during rainy season, But the lowest PWC is not necessary related to summer desiccation.

The percentage relative water content (RWC) values varied from 61.48 to 79.84 in *Parthenium* plant. Highest RWC values in Nov-Dec. and lowest in May-June were observed. The Highest values of water deficit were recorded during May-June (Summer season) and the lowest in July-August.

(Rainy Season).

Bound water which is unfree or combined was found to be highest in the months of July-August and lowest during May-June which was maximum during rainy season.

It has been observed that rate of transpiration varied with the seasons in the plant species studied. The maximum water loss was during rainy season which decreased during summer and became minimum in winter. This shows that the rate of transpiration is related to the availability of moisture

present in the soil and in the atmosphere. In the present investigation itwas also observed that transpiration rate was higher in noon and morning hours in all the seasons. Higher rate of transpiration in the plant in the noon hours throughout the year may be helpful in providing cooling effect for the plant and thus ensuring its survival. This phenomenon of transpiration could also be attributed to the plant's ability to control and regulate their stomatal opening in a way according to the requirement so that it can minimize its excessive water loss quite effectively. It is obvious that comparisons of plant survival cannot provide comparative information concerning water balance and drought tolerance adaptations in the species studied. However, survival test under water limited conditions provide a relative simple technique to preliminary screen material for potential genetic differences.

Water is an essential constituent of any plant, excess water loss from the plant body often results into dehydration of the protoplasm, as a consequence of which most of the bio-chemical processes are adversely affected. Water imbalance in a plant is often marked with the appearance of certain chemical compounds in its various organs; more particularly in leaves. The plant species examined exhibited higher values of sugar content during rainy season as compared to winter; followed by summer and slight, variation regarding in soluble sugars was observed during rainy and winter season. Overall there has not been much variation throughout the year. Therefore it can be concluded that the plant studied does not get affected much by seasonal variations or water stress as far as its metabolic activities are concerned as it is able to maintain itself under diverse conditions by continuing the bio-chemical and metabolic processes normally and steadily. The nutritive pattern of plants are very important especially in those which

are well established. Nutritive values are mainly concerned with protein and nitrogen content of a plant species. In the present investigation the plant species studied exhibited the higher protein values during rainy season followed by winter and least during summer. With regard to nitrogen content of the plant, maximum value was recorded during winter followed by rainy and minimum in summer season.

Chlorophyll content in a plant species is directly influenced by environmental factors like, soil moisture, water stress, temperature, salinity, etc. During the present course of study, the amount of chlorophyll a was invariably found to be higher as compared to chlorophyll b in the *Parthenium* plant. The species exhibited highest values during rainy followed by winter and least in summer season. The values for caotenoids were also found to be maximum during rainy season and minimum during winter or summer season as there is not much variation in the values of caretenoids during these two seasons.

In the present study, an effort was made to assess the value of chlorophyll, nitrogen and sugar contents in the *Parthenium* plant leaves under the sun and shade. In the investigation it was noted that there is close link between percentage of moisture thus the above said parameters except reducing sugar content whose higher value was recorded in sun leaves. Therefore it may be concluded that moisture in the soil do have positive effect on the chlorophyll and nitrogen content of the plant species studied.

The decrease in total chlorophyll in the plant species is mainly attributed to the destruction of chlorophyll a which is considered to be more sensitive than chlorophyll b.

Successful adaptation and survival mechanism have enabled this weed to defy all methods of control by man. The success of bio-control agent is often limited by adverse environmental condition. The combined effect of several agents, each responding differently to climatic factors and each abundant in different condition is what is desirable for fool proof control of the weed from any ecosystem. Biological control and use of botanical agents are not only environmentally benign methods but also self sustaining and economical in long term run. These, therefore, warrant special attention and encouragement. Since *Parthenium* has become a menace in different parts of the country, several methods are being recommended to suppress its growth, but none appears to have worked satisfactory, as each suffers from one or more limitations, such as inefficiency, prohibitive cost, impracticability, pollution of environment and only limited relief etc. In view of above, developing the integrated approach towards *Parthenium* management seems to be the only promising strategy. Enshrining this perception in the objective of the present investigation, various methods to control the *Parthenium* population were tried and the results obtained are presented in the preceding chapters.

Manual method to remove the *Parthenium* population was done, in which plants were removed from a marked area, both by cutting above the ground level and by uprooting the whole plant to assess the emergence potential of the plant. It was observed that the number of emerged plant is more in the test plot in which *Parthenium* was removed by cutting above the ground level than those which were uprooted. Thus it is suggested that if the plants are to be removed mechanically, they should be uprooted and then they should be burnt so as to check the dispersal of the seed.

Under the chemical practice two herbicides viz. 2, 4D sodium salt and Round up (Glyphosate) with different level of doses, to control the weed and the effect of herbicides on chlorophyll disintegration, were applied. I was evident from the data recorded that round up has supremacy over 2, 4D sodium salt as for as suppression of *Parthenium* weed is concerned. Maximum suppression was observed with higher doses of chemicals applied. In the course of this study, it was noted that disintegration of pigments was higher in higher doses of herbicides sprayed on the *Parthenium* plant. Under the biological control of *Parthenium* plant, a fungal species viz. *Fusarium oxysporum* was tried and results obtained showed that seed, inoculation, soil inoculation and spray of the fungus on seed caused seed rot and seedling mortality. From the observation it was noted that spray on seed is effective marginally than that of seed inoculation by mixing and soil inoculation as maximum values with regard to the percentage reduction in germination were recorded when the seeds were subjected to the direct spray.

The spray of mycelium suspension on the growth parameters viz. height, no. of flowers and no. of branches/ plant of the weed showed maximum reduction in height (8.7%) of the weed after 25 days of spray and maximum reduction in no. of branches/plant (16.3) was recorded after 16 days of spraying with regard to reduction in no. of flowers/ plant maximum value (24.2) was observed 35 days after sowing. An effort was made to assess different amount of inoculum of *Fusarium oxysporum* at different growth stages viz. vegetative stage before flowering and after flowering of *Parthenium hysterophorus.* The observations recorded in this regard, exhibited that the spray of 100, 150 and 200 g wet mycilium per litre of

water at vegetative stage and before flowering stage could reduce plant height, no. of branches and flowers per plant but maximum reduction in these parameters was obtained when *F. oxysporum* was sprayed at 150-200 g /litre of water at vegetative and before the flowering stage. When the efficacy of treatment was analyzed in terms of its effect on different parts of the plant viz. height, branching and flowers, it was noted that flowers appeared were observed to be maximum sensitive.

The data on the effect of competitive plants and their density on the growth and flowering of *Parthenium* depicted that *Parthenium* population was substantially lower under *Cassia uniflora* followed by *Abutilon indicum* and *Tagetes erecta* as against control (*Parthenium* only). Maximum reduction (71%) in dry weight of *Parthenium* was obtained by *Cassia uniflora,* minimum (67%) by *Abutilon indicum* and least (64%) by *Tagetes erecta.* Similar trend was observed in reduction of flower heads of *Parthenium* by the above said botanical agents (BAs). The young seedlings of *Cassia uniflora* and *Abutilon indicum* are larger than those of *Parthenium* with well developed root and shoot system. This advantage enables them to suppress the vegetative growth of *Parthenium*, delay flowering and reduce the number of capitula as well as seeds.

The root extracts of the above said competitive plants, prepared in different concentrations, were analyzed for its effect on seed vigour, percentage germination, radicle length and plumule length of *Parthenium.* Results thus obtained indicated a reduction in all the above parameters. Maximum reduction in these parameters was observed with higher

percentage of concentration. i.e. maximum in 100 percent concentrationand least in 25 percent concentration.

As an effective alternative to conventional bio-logical control methods, exploitation of dominant crop and plant species to replace *Parthenium* by their vigorous growth or allelopathic activity has been successfully demonstrated. In the present study, *Cassia uniflora*, *Abutilon indicum* and *Tagetes erecta* have produced encouraging results that indicate their potential to be used as biological means of*Parthenium* control. *Cassia uniflora*, the introduced plant though suppresses the *Parthenium* growth, its establishment is not uniform over the ecological regions. Identification & establishment of indigenous plant *Cassia uniflora*, capable of suppressing *Parthenium* would be of practical use.

In this direction, the present study has indicated the possibility of using *Cassia uniflora*, *Abutilon indicum* and *Tagetes erecta* to manage the *Parthenium* menace in unattended larger areas, where agronomic practices are not followed otherwise.

During the course of this investigation with adaptive research carried out, it was realized that only an integrated approach now termed as "Integrated *Parthenium* weed management (IPWM)" can be effective in suppressing this weed. If a concerted effort is made adopting IPWM strategy, the results will be visible in the second year and in the third year the *Parthenium* population will come down to a considerable extent.

At present there is a particular cause for optimism concerning the use of natural enemies as classical biological control agents for the management of exotic weeds. The three main aims of sustainable weed management in

any ecosystem. be it agricultural or conservation, social desirability, ecological safety and economic viability are to be taken into account.

From the results of the present studies an assessment could be made regarding the potential of fungal pathogens as classical biological control agents of *Parthenium* weed.

It would seem to be reasonable to conclude that there is no single agent/method which could provide the "magic control bullet," never the less, the potential of natural enemies should not be under estimated, especially if they are used in association, as obviously occurs within the native range and in comination with alternative management practices. It is, therefore, appropriate to analyse and discuss the specific problems relating to control of *P hysterophorus*. So that a strategy for its sustainable management can be developed.

As with other problematic weeds, classical biological control of*Parthenium* may lie in introducing a suite of natural enemies which hopefully, would act synergistically and preferably, attack different parts of the plant, as the objective of the current biological control programme is to search for better adopted species. If different management practices are to combined then their over all impact on *Parthenium* population could be dramatic, however, their true potential needs to be realized, and most importantly with patience what seems certain is that there will be no short term, spectacular success with classical biological control of *Parthenium* weed. But there could be a gradual reduction in weed vigour particularly in its prolific seed producing ability, which in long term could have a significant negative impact on weed

population dynamics. More conventional control tactices could be employed to further erode weed competitiveness.

What are the alternative control measures and what is their potential? Mechanical control. in general, has given poor results, mainly because most methods seem to spread the seed or encourage regeneration. Hand pulling may be effective on a local scale but, obviously, it is labour intensive and there are risks involved, as direct contact with this weed is not advisable keeping in view the various allergies involved due to this.

Chemical herbicides active against *Parthenium* weed are many and have been tried and tested. However, application of such products over large area is not economically viable and in the long term, ecologically undesirable. Moreover, the *Parthenium* seed bank often remains intact to reinfest the treated areas. Targeted application of herbicides to suppress the weed in urban situations may be the most efficient and cost-effective way of employing these chemicals to reduce the health problems posed by *P hysterophorus*. Virtually the same arguments can be used when the use of mycoherbicides, based on local opportunistic pathogens, is proposed. The economics involved would be similar, although, environmentally, mycoherbicides may prove to be more acceptable for sustainable management in urban areas.

Considerable interest has been generated recently in the use of antagonistic plants, and significant research has already been under taken, exploiting the allelopathic properties of local plants particularly from the members of Leguminosae family. Once again, however, the economics of this exercise, certainly over large areas of weed infestation are dubious, as

are the ecological implications. For example one of the favoured plant species, *Cassia uniflora* is a major host of *Bemisia* White flies. Direct application of their allelopathic substance is another suggested approach but this is no different in economic terms, to the drawbacks discussed for chemicals or mycoherbicides.

The statement quoted earlier, remains as viable today as it did years ago and that classical biological control offers the best solution for sustainable management of *Parthenium* weed, particularly since it fits readily into an integrated management strategy.

The judicious use of alternative control measures, when and where necessary, could be employed, specifically to reduce the impact of the weed on human health. A concerted effort, whereby more natural enemies or additional types (eco-types, patho-types) are evaluated for introduction as classical biological control agents will be necessary if the *Parthenium* problem is ever to be successfully addressed.

In the light of the present investigation and adaptive research carried out the suggestions for the future perspective regarding the management of the stated menace, could be summarized as:-

1. There is a need for community efforts in manual removal of the weed before it starts flowering.
2. Educate land holders on best management practices for *Parthenium* using land holders experiences.
3. Educate the broader community about the potential problems associated with *Parthenium.*
4. Educate the community in measures to prevent the spread.

5. Establish research and development in the field
6. Limited use of recommended weedicide can be adopted in suitable areas.
7. The role of plant species in competitive displacement of *Parthenium* has to be further evaluated. Particularly the plant selected for displacement should have some economic value and should not pose health/environment problems.
8. Maximum effort should be directed towards importation of host specific insects. These may, however, be extensively tested in the quarantine for their specificity to *Parthenium.*
9. There is a need for interaction between different scientists and laboratories so that an integrated management of *Parthenium* is evolved.
10. The Government may enact legislation for removal of *Parthenium* in public place.
11. Detailed study of herbicide action on the biology and ecology of *Parthenium* should be done before recommending any herbicide because of the fact that *Parthenium* is very hardy and may soon develop resistance against herbicides.
12. As *Parthenium* germinates throughout the year, application of pre and post emergent herbicide in sequence may give effective control of *Parthenium.* This approach need in depth- investigation.
13. Development of newer group of herbicides with the attributes of economically cheap, persistent but having less residual effects are imperative.
14. Most sensitive stage of growth of *Parthenium* should be identified for effective management.

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APPENDIX

APPENDIX

ANOVA FOR TABLE -12 (Chl. a).

Source of Variation	df	S.S	M.S.	F. Value	F(5%)	Result
Replicates	2	1.23	0.61			
d (doses)	3	123.50	41.16	128.30	3.34	S
t (treatments)	1	0.62	0.62	1.94	4.60	NS
d x t (interaction)	3	7.46	2.48	7.76	3.34	S
Error	14	4.49	0.32			
Total	23	137.30	45.19	138.00	11.28	

ANOVA FOR TABLE -12 (Chl.b).

Source of Variation	df	S.S	M.S.	F. Value	F(5%)	Result
Replicates	2	0.10	0.05			
d (doses)	3	28.69	9.56	428.60	3.34	S
t (treatments)	1	0.007	0.007	0.35	4.60	NS
d x t (interaction)	3	0.002	0.00	0.04	3.34	NS
Error	14	0.31	0.02			
Total	23	29.10	9.63	428.99	11.28	

ANOVA FOR TABLE -12 (Caretenoids).

Source of Variation	df	S.S	M.S.	F. Value	F (5%)	Result
Replicates	2	0.51	0.25			
d (doses)	3	9.8	3.27	59.23	3.34	S
t (treatments)	1	0.07	0.07	1.31	4.60	NS
t x d (interaction)	3	0.02	0.008	0.15	3.34	NS
Error	14	0.77	0.05			
Total	23	11.19	3.64	60.69	11.28	

ANOVA FOR TABLE-15:(Height/pl at vegetative stage).

Source of Variation	df	S.S.	M.S.	F. Value	F (5%)	Result
Replicates	2	116.28	58.14	111.63		
t(treatment)	3	121.03	40.34	77.46	4.76	S
Error	6	3.12	0.52			
Total	11	240.43	99.00	189.09	4.76	

ANOVA FOR TABLE-15:(Height/pl before flowering).

Source of Variation	df	S.S.	M.S.	F. Value	F(5%)	Result
Replicates	2	30.83	15.41	1.00		
t(treatment)	3	198.40	66.13	4.30	4.76	NS
Error	6	92.19	15.36			
Total	11	321.42	96.90	5.30	4.76	

ANOVA FOR TABLE-15:(Height/pl after flowering).

Source of Variation	df	S.S.	M.S.	F. Value	F(5%)	Result
Replicates	2	165.62	82.81	9.32		
t(treatment)	3	14.44	4.81	0.54	4.76	
Error	6	53.28	8.88			
Total	11	233.34	96.50	9.86	4.76	

ANOVA FOR TABLE-15:(branching/pl at vegetative Stage).

Source of Variation	df	S.S.	M.S.	F. Value	F(5%)	Result
Replicates	2	1.50	0.75	0.57		
t(treatment)	3	1.66	0.55	0.43	4.76	NS
Error	6	7.83	1.30			
Total	11	10.99	2.60	1.00	4.76	

ANOVA FOR TABLE-15:(branching/pl before flowering).

Source of Variation	df	S.S.	M.S.	F. Value	F(5%)	Result
Replicates	2	4.66	2.33	1.24		
t(treatment)	3	0.66	0.22	0.12	4.76	NS
Error	6	11.33	1.88			
Total	11	16.65	4.43	1.36	4.76	

ANOVA FOR TABLE-15:(branching/pl after flowering).

Source of Variation	df	S.S.	M.S.	F. Value	F (5%)	Result
Replicates	2	2.66	1.33	0.86		
t(treatment)	3	0.91	0.30	0.20	4.76	NS
Error	6	9.33	1.55			
Total	11	12.90	3.18	1.06	4.76	

ANOVA FOR TABLE-15:(No.of flowers /pl at vegetative stage).

Source of Variation	df	S.S.	M.S.	F. Value	F(5%)	Result
Replicates	2	125.16	62.58	0.32		
t(treatment)	3	6604.25	2201.41	11.10	4.76	NS
Error	6	1189.50	198.25			
Total	11	7918.91	2462.24	11.42	4.76	

ANOVA FOR TABLE-15:(No. of flowers /pl before flowering).

Source of Variation	df	S.S.	M.S.	F. Value	F (5%)	Result
Replicates	2	2.16	1.08	0.02		
t(treatment)	3	7634.25	2544.75	43.56	4.76	S
Error	6	350.50	58.41			
Total	11	7987.91	2604.24	43.58	4.76	

ANOVA FOR TABLE-15:(No.of flowers /pl after flowering).

Source of Variation	df	S.S.	M.S.	F. Value	F(5%)	Result
Replicates	2	16.16	8.08	0.25		
t(treatment)	3	6363.66	2121.22	64.99	4.76	S
Error	6	195.83	32.63			
Total	11	6575.65	2161.93	65.24	4.76	

ANOVA FOR TABLE-16:(% Reduction in dry weight).

Source of Variation	df	S.S.	M.S.	F. Value	F (5%)	Result
Replicates	2	111.80	55.90	4.96		
t(treatment)	9	3011.63	334.62	29.69	2.47	S
Error	18	202.86	11.27			
Total	29	3326.29	401.79	34.65	2.47	

ANOVA FOR TABLE-16:(% Reduction in flower heads).

Source of Variation	df	S.S.	M.S.	F. Value	F (5%)	Result
Replicates	2	24.86	12.43	1.07		
t(treatment)	9	5356.70	595.18	51.06	2.47	S
Error	18	209.80	11.65			
Total	29	5591.36	619.26	52.13	2.47	

ANOVA FOR TABLE - 17 (% germination).

Source of Variation	df	S.S	M.S.	F. Value	F (5%)	Result
Replicates	2	50.16	25.08	0.19		
t(treatment)	3	6937.55	2312.51	17.24	3.05	S
d (doses)	2	5041.50	2520.75	18.79	3.44	S
t x d (interaction)	6	3242.94	540.49	4.03	2.55	S
Error	22	2951.83	134.17			
Total	35	18223.98	5533.00	40.25	9.04	

ANOVA FOR TABLE- 17 (seeds vigour).

Source of Variation	df	S.S	M.S.	F. Value	F (5%)	Result
Replicates	2	1.23	0.61	1.37		
t(treatment)	3	41.25	13.75	30.39	3.05	S
d (doses)	2	44.79	22.39	49.49	3.44	S
t x d (interaction)	6	15.22	2.53	5.61	2.55	S
Error	22	9.95	0.45			
Total	35	112.44	39.73	86.86	9.04	

ANOVA FOR TABLE - 17 (Radicle length).

Source of Variation	Df	S.S	M.S.	F. Value	F(5%)	Result
Replicates	2	0.04	0.02	2.83		
t(treatment)	3	1.72	0.57	68.44	3.05	S
d (doses)	2	0.32	0.16	19.43	3.44	S
t x d (interaction)	6	0.13	0.02	2.67	2.55	S
Error	22	0.18	0.00			
Total	35	2.39	0.77	93.37	9.04	

ANOVA FOR TABLE- 17 (Plumule length).

Source of Variation	df	S.S	M.S.	F. Value	F (5%)	Result
Replicates	2	0.03	0.01	0.62		
t(treatment)	3	1.84	0.61	24.81	3.05	S
d (doses)	2	0.55	0.27	11.11	3.44	S
t x d (interaction)	6	0.28	0.04	1.93	2.55	S
Error	22	0.54	0.02			
Total	35	3.24	0.95	38.47	9.04	

ANOVA FOR TABLE- 18.

Source of Variation	df	S.S	M.S.	F. Value	F(5%)	Result
Replicates	2	66.06	33.03	1.13		
t(treatments)	9	8267.63	918.62	31.48	2.47	S
Error	18	525.26	29.18			
Total	29	8858.95	980.83	32.61	2.47	